Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

CIRCULAR No. 193 DECEMBER, 1931
UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

CROP ROTATION AND TILLAGE EXPERIMENTS AT THE SAN ANTONIO (TEXAS) FIELD STATION

By George T. Ratliffe, *Associate Agronomist*, and I. M. Atkins, *Junior Agronomist, Division of Western Irrigation Agriculture, Bureau of Plant Industry*

CONTENTS

	Page
Introduction	1
Soil	2
Climatic conditions	2
History and plan of rotation experiments	5
List of rotations	6
Cultural practices	8
Crop yields in detail	9
Oats	9
Corn	11
Milo	12
Sorghum	13
Sudan grass	14
Cotton	14
Seasonal fluctuation in yield	16
Comparison of effects of rotations and cultural treatments on crop yields	17
Oats	18
Corn	22
Milo	25
Sorghum	27
Sudan grass	29
Cotton	29
Comparative merits of different crops and rotations	33
Influence of cotton root rot on cotton yields	35
Summary	37
Literature cited	39

INTRODUCTION

The experiments herein reported were conducted at the United States San Antonio Field Station, located about 6 miles south of the city of San Antonio, Tex. The station lies near the line between the black prairie region or "black lands" of Texas and the Rio Grande plain. The soil is chiefly derived from the weathering of limestone rock but is somewhat modified by alluvial deposits washed down from higher lands to the north. Northwest from San Antonio the topography rapidly becomes rough, and the Edwards Plateau region lies within a short distance of the city. To the south the soil gradually changes to a more sandy type and the topography is gently rolling. Throughout this region the lime content of the soil is very high at the surface, and limestone gravel is reached within 3 feet of the surface in many places.

The principal cash crop of the region is cotton. Secondary crops are corn, forage sorghum, grain sorghum, and oats. On relatively small areas where irrigation is possible, either from wells or from streams, truck crops are an important source of income. Dairying is increasing and on the larger ranches the production of beef cattle has been an important industry for many years, while recently the raising of goats is being featured in certain localities. Corn and grain sorghum are raised principally for consumption on the farms, although they are grown for sale by a few farmers. Practically none, however, is shipped from the region. Oats are grown chiefly as a winter pasture crop, and during favorable seasons often serve as an important source of feed for the stock. The production of oats for grain or hay is incidental, as the crop is usually planted for pasture, and only when conditions are favorable is it left for hay or grain. Forage sorghum, especially the Sumac variety, is used extensively for hay, although Sudan grass is gaining in importance as a hay crop. In certain sections north of San Antonio wheat is grown to some extent. Practically no legume crops are grown in this area, partly because of the semiarid conditions and partly because they are very susceptible to the same disease that causes cotton root rot.

SOIL

The soil on the station is variable, not only from field to field but frequently within plots. This variation includes depth, lime content, and structure, as well as general fertility and water-holding capacity. The soil at the north end of the area devoted to the rotations varies from light gray to dark brown in color and in places near the west edge of field B5 is less than 2 feet in depth, being underlain by a finely divided white limestone gravel. (Fig. 1.) At the east end of the same plots in field B5, on which the soil is so shallow at the west end, the limestone is not reached within the 6-foot zone. Over most of fields A4, A5, B4, and B5, however, the topsoil is 2 to 3 feet deep. The subsoil is, for the most part, a rather heavy clay, chocolate brown to black in color, underlain by a stratum of caliche gravel. In topography these four north fields in the rotations are very nearly level. Starting at the north end of fields A6 and B6, the land has an appreciable grade to the south and west. The soil is progressively deeper down the slope, and at the south end of these fields the heavy black soil extends to a depth of at least 10 feet. The soil of these fields is more productive and has a greater water-holding capacity than that of the other fields. All this soil is of a texture that is sticky and difficult to work unless moisture conditions are favorable.

In considering the data presented in the following pages it will be apparent that these soil variations have often influenced crop yields to a greater extent than the various crop sequences or the treatments applied.

CLIMATIC CONDITIONS

The climate of the region fluctuates from humid to semiarid. Droughts of many weeks' duration may occur at any season of the year, but they are more common during the summer months. The mean rainfall for the period 1907 to 1929 was 26.46 inches as measured at the field station. If properly distributed, this precipitation would insure fair crop production, yet the irregular manner in which it occurs makes crop production uncertain. The rainfall has ranged from a minimum of 13.14 inches in 1909 to a maximum of 47.63 inches in 1919. Table 1 shows the record of rainfall by months for the period 1907 to 1929.

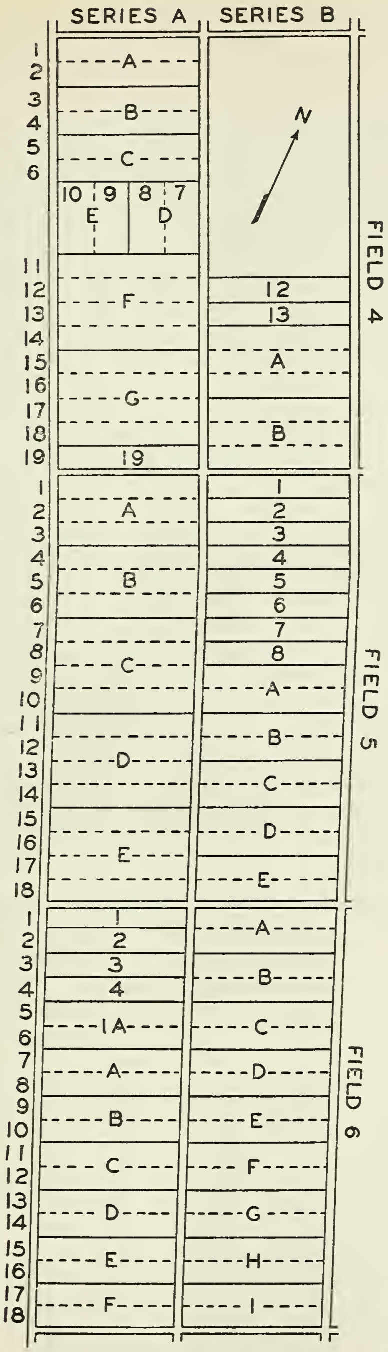

FIGURE 1.—Diagram of rotation experiments at the San Antonio field station

TABLE 1.—*Monthly and annual precipitation (in inches) at the San Antonio field station, 1907–1929*

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1907	0.56	1.72	1.70	4.50	2.81	0.31	2.65	0.39	0.64	2.98	6.78	0.64	25.68
1908	.47	2.61	1.27	2.39	5.44	.88	1.37	3.79	2.59	1.62	2.87	1.50	26.80
1909	0	.41	1.12	.85	1.72	.72	2.86	1.75	.29	1.20	.27	1.95	13.14
1910	1.75	.68	.21	4.40	1.99	2.02	1.12	.45	.60	3.76	1.30	1.76	20.04
1911	.14	1.77	3.30	4.93	1.41	.08	1.14	2.16	1.24	3.10	2.13	1.53	22.93
1912	.32	6.26	2.47	1.82	1.64	3.42	.08	.25	1.55	2.90	1.76	3.91	26.38
1913	1.01	1.95	2.74	1.32	2.23	4.27	.27	1.21	9.41	4.06	4.01	4.23	36.71
1914	.20	1.43	1.13	6.27	6.62	.04	0	4.28	1.87	3.89	4.20	1.43	31.36
1915	.48	1.72	1.31	9.05	2.50	0	1.08	3.48	3.21	1.90	.41	1.50	26.64
1916	2.30	0	.53	1.61	3.79	.82	4.72	2.25	4.16	4.48	2.58	.38	27.62
1917	.81	.46	.13	.74	3.41	.04	3.40	.32	1.73	1.54	.63	.01	13.22
1918	.04	1.72	.56	3.83	3.36	2.90	1.89	1.33	2.08	3.66	2.32	3.38	27.07
1919	3.88	1.57	1.74	2.52	2.86	5.79	7.60	2.22	7.06	10.06	.51	1.82	47.63
1920	4.00	.19	.49	.51	3.78	5.10	1.66	2.39	.03	1.91	1.97	.10	22.13
1921	1.76	.30	5.41	4.79	.62	4.40	1.40	.02	6.77	.90	1.94	.08	28.39
1922	.89	.97	4.33	7.12	3.93	4.73	.12	.02	1.07	4.80	.89	.09	28.96
1923	.38	6.08	2.81	2.69	1.67	2.16	2.16	2.50	3.02	1.38	3.99	4.59	33.43
1924	.81	3.27	.95	2.20	5.05	6.59	0	0	2.14	.25	.17	2.67	24.10
1925	.20	.06	.30	.21	2.11	.96	.57	1.66	4.00	1.53	1.70	1.64	14.94
1926	2.83	.10	4.68	6.65	1.65	3.92	1.39	.38	.39	2.54	1.63	2.14	28.30
1927	.67	1.84	2.17	1.75	1.72	7.71	.36	.05	1.83	2.10	Trace	2.30	22.50
1928	.83	2.30	2.05	2.03	5.35	4.65	.58	2.66	4.97	1.49	1.89	2.41	31.21
1929	1.35	.15	2.64	2.56	8.23	2.34	3.12	.05	2.38	1.87	2.95	1.81	29.45
Mean	1.12	1.63	1.91	3.25	3.21	2.78	1.72	1.46	2.74	2.78	2.04	1.82	26.46

Temperatures are quite mild, and the minimum rarely goes below 15° F. The frost-free period averages 259 days, and winter crops are rarely hurt by cold weather. The summers are long, with moderately high temperatures. The wind movement is relatively high throughout the year. Evaporation is high during the summer months, and consequently small rains and showers during the growing season are of very little value to crop plants. Oats are grown primarily for winter pasture, and except when occasionally frozen down they grow all winter if moisture is available. When left for grain, oats usually mature in May. Corn and grain sorghum are planted early in March and usually mature in July. Sorgo and Sudan grass are planted in March and produce from one to three crops, depending upon the seasonal rainfall. Cotton is usually planted in early April.

TABLE 2.—*Yearly summaries of climatological data recorded at the San Antonio field station, 1907–1929*

Year	Last frost in spring	First frost in fall	Frost-free period	Temperature for year			Evaporation	Mean wind velocity
				Maximum	Minimum	Mean		
			Days	°*F.*	°*F.*	°*F.*	*Inches*	*Miles per hour*
1907	Feb. 8	Nov. 11	276	108	27	71.2	65.06	--------
1908	Feb. 20	Nov. 14	268	103	18	69.0	61.80	--------
1909	Feb. 25	Dec. 6	284	104	17	68.4	76.33	--------
1910	Feb. 24	Oct. 28	246	107	12	69.0	67.53	--------
1911	do	Nov. 12	261	105	13	70.6	70.86	5.1
1912	Feb. 26	Nov. 2	250	105	16	67.3	67.27	3.5
1913	Mar. 26	Oct. 26	214	102	20	67.2	58.68	3.0
1914	Apr. 8	Nov. 19	225	104	21	67.0	60.50	2.5
1915	Mar. 23	Nov. 14	236	102	21	68.4	63.92	2.9
1916	Feb. 19	Nov. 13	268	103	18	69.8	69.66	3.5
1917	Mar. 4	Oct. 29	239	107	14	68.6	76.67	3.7
1918	Feb. 21	Nov. 28	280	105	9	68.5	69.84	3.7
1919	Feb. 28	Nov. 29	274	98	21	66.8	50.56	2.7
1920	Apr. 4	Nov. 14	224	101	19	67.8	60.12	3.0
1921	Feb. 23	Dec. 4	284	102	25	70.2	67.13	3.8
1922	Mar. 3	Dec. 18	290	102	21	69.2	66.32	3.7
1923	Mar. 19	Dec. 13	269	103	20	68.1	62.36	3.8
1924	Mar. 13	Nov. 24	256	104	20	68.0	65.22	3.8
1925	Feb. 11	Nov. 15	277	104	19	70.1	77.12	4.3
1926	Feb. 19	Nov. 9	263	102	21	68.6	62.15	3.1
1927	Mar. 1	Dec. 2	276	105	20	71.0	67.10	3.7
1928	Mar. 16	Nov. 20	249	103	16	69.6	65.34	3.6
1929	Mar. 1	Nov. 14	258	102	10	67.9	55.38	3.1
Mean	Mar. 4	Nov. 18	259	--------	--------	68.8	65.52	3.5

In order to indicate the general climatic conditions of the region, other than precipitation, Table 2 is presented, giving data for each year that records have been kept.

HISTORY AND PLAN OF ROTATION EXPERIMENTS

Rotation experiments were first begun on the San Antonio field station in 1906, when a series of ⅒-acre plots were laid out in fields that are now known as A5 and B5. During the season of 1906 the plots on A5 were used for some experiments in tillage and only B5 was definitely started as a rotation field. In 1907 rotations were planned for both fields. In 1908 another field, A6, was laid out and the series of experiments extended to it. Field B6 was held fallow in 1908 for the purpose of eradicating Johnson grass but was included the following year.

The results through 1908 demonstrated that the ⅒-acre plots, 1 rod wide by 16 rods long, were not satisfactory. In the fall of 1908 it was decided to resurvey the fields into ¼-acre plots and plan a new series of rotations. In 1909 the rotations in fields 5 and 6 were started. These included crops of corn, cotton, forage sorghum, oats for hay, and oats for grain. Cowpeas were also grown in certain rotations as a green-manure crop. In 1910 six plots were laid out at the north end of field A4 for the purpose of testing the value of alternate cropping and fallow with corn, cotton, and oats. In 1911 four ⅕-acre plots were added to this field. These plots were leveled and borders were thrown up around them to prevent the loss of rainfall by run-off. The same year the remainder of A4 was devoted to rotation work. In 1914 plot B4–12, continuously cropped to drilled sorghum with an annual application of barnyard manure, was added. As the work progressed it was found that certain crops were not so well suited to the region as others, and certain substitutions and additions were made during the first few years. Field peas were found to be more dependable as a green-manure crop than cowpeas and were substituted in a number of cases. Milo was found to be adapted to the region and was substituted for corn in a number of rotations in 1912 and 1913. Sudan grass was added in 1911 and 1912. In 1910 six plots were laid out in field A4 for the purpose of testing the merits of biennial cropping. Since 1914 no change has been made in the rotation experiments. The plan of the rotation experiments, showing their location with reference to one another, is shown in Figure 1.

The rotation and tillage experiments, conducted since 1914, occupy portions of two series of fields, designated on the station map as A and B. Each series contains three 5-acre fields, which are in turn divided into eighteen ¼-acre plots, except field A4, in which there are fifteen ¼-acre plots and four ⅕-acre plots. Only a part of field B4 is included in these experiments. Each ¼-acre plot is 41.25 by 264 feet, with an alley of 4.75 feet between plots. This makes each plot 46 feet wide as measured from the center of the alley on one side to the center of the next alley. When planted to row crops this permits the planting of 10 rows spaced 4.1 feet apart. The ⅕-acre plots are 132 by 66 feet and accommodate 32 rows spaced 4.1 feet apart. No alleyway is provided between plots in this series, the crops being planted up to the edge of the adjoining plot. As has been explained, these plots have a low border of earth around the periphery of each to prevent run-off of rainfall. The entire experiment consists of 35 rotations and 15 plots continuously cropped. There are twenty-six 2-year rotations, four 3-year rotations, and five 4-year rotations. The number of plots devoted to a particular rotation is equal to the number of years the rotation covers. Thus a 2-year rotation covers an area of 2 plots, a 3-year rotation an area of 3 plots, and a 4-year rotation an area of 4 plots. In this way each crop appears in the rotation each year.

When the work was first started very little was known about what crops were best suited to the conditions of the San Antonio region. Cotton, corn, sorghum, and oats for hay and pasture were the principal crops grown by farmers at that time, and the rotations were planned to feature these crops. In addition to ascertaining the crops adapted to the region, a further objective was to determine the best rotations and cultural practices, by comparing the yields of each crop when grown continuously on the same land with the yields in 2-year, 3-year, and 4-year rotations. The effects of barnyard manure, green-manure crops, subsoiling, and time of plowing were also to be determined in relation to these crops. Some rotations included combinations of the above cultural practices.

The system of designating plots and rotations is as follows: The first letter refers to the series and the first numeral to the field; the next character, if a numeral, refers to the plot; if a letter, to the rotation. Where cotton appears in the rotation twice in rotations A5–C, A5–D, and A5–E, each plot of cotton is identified throughout the cycle by a numeral following the second letter. Thus, the plot in which cotton follows oats throughout the cycle is designated A5–C1, while the plot in which cotton follows milo is designated A5–C2.

LIST OF ROTATIONS

A list of the rotations follows. Unless otherwise stated, the first crop was harvested in 1909.

FIELD A4

Rotation A (begun in 1910)

Plot No.
1. Fallow.
2. Cotton. (Plowed in November.)

Rotation B (begun in 1910)

3. Fallow.
4. Corn. (Plowed in July.)

Rotation C (begun in 1910)

5. Fallow.
6. Oats. (Plowed in June.)

Rotation D, bordered (begun in 1911)

7. Cotton. (Plowed in November.)
8. Corn. (Plowed in July.)

Rotation E, bordered (begun in 1911)

Plot No.
9. Sorghum, 4.1-foot rows. (Plowed in November.)
10. Fallow.

Rotation F (begun in 1913)

11. Oats for grain. (Plowed in June.)
12. Grain sorghum, field peas. (Plowed under in spring.)
13. Sorghum, early variety. (Plowed in November.)
14. Cotton. (Plowed in fall.)

Rotation G (begun in 1913)

15. Oats for grain. (Plowed in June.)
16. Grain sorghum, field peas for hay. (Plowed in spring.)
17. Sorghum, early variety. (Plowed in November.)
18. Cotton. (Plowed in fall.)

Begun in 1913

Plot No.

19. Cotton, continuous, field peas. (Plowed under in spring.)

Field A5

Rotation A

1. Oats for hay. (Plowed in June.)
2. Cotton. (Plowed in November.)
3. Grain sorghum. (Plowed in July.)

Rotation B

4. Oats for hay. (Plowed in June.)
5. Cotton, manured. (Plowed in November.)
6. Grain sorghum. (Plowed in July.)

Rotation C

7. Oats for grain. (Plowed in June.)
8. Cotton. (Plowed in November.)
9. Grain sorghum. (Plowed in July.)
10. Cotton. (Plowed in fall.)

Rotation D

11. Oats for grain, cowpeas. (Plowed under in fall.)
12. Cotton. (Plowed in November.)
13. Grain sorghum, manured. (Plowed in July.)
14. Cotton. (Plowed in fall.)

Rotation E

15. Oats for grain, cowpeas. (Plowed under and subsoiled in fall.)
16. Cotton. (Plowed in November.)
17. Grain sorghum, manured. (Plowed and subsoiled in July.)
18. Cotton. (Plowed in fall.)

Field A6

1. Grain sorghum. (Plowed in July. Begun in 1912.)
2. Grain sorghum, manured. (Plowed in July. Begun in 1912.)
3. Cotton. (Plowed in November.)
4. Sorghum for forage, 4.1-foot rows. (Plowed in November.)

Rotation 1A (begun in 1912)

5. Oats for hay. (Plowed in May.)
6. Grain sorghum. (Plowed in July.)

Rotation A

7. Corn. (Plowed in July.)
8. Oats for hay. (Plowed in May.)

Rotation B

Plot No.

9. Corn. (Plowed in July.)
10. Oats for hay. (Plowed in November.)

Rotation C

11. Corn. (Plowed in July.)
12. Oats for hay. (Plowed and subsoiled in May.)

Rotation D

13. Corn. (Plowed in July.)
14. Grain sorghum. (Plowed in July.)

Rotation E

15. Corn. (Plowed in July.)
16. Oats for grain, manured. (Plowed and subsoiled in June.)

Rotation F

17. Sudan grass, manured. (Plowed in November.)
18. Corn. (Plowed in July.)

Field B4

Continuous cropping

12. Sorghum, manured. (Plowed in November. Begun in 1914.)
13. Sorghum, manured every two years. (Plowed in November. Begun in 1913.)

Rotation A

14. Sudan grass. (Plowed in November.)
15. Cotton. (Plowed in November.)
16. Grain sorghum. (Plowed in July.)

Rotation B

17. Oats for hay, field peas. (Plowed under in spring.)
18. Cotton. (Plowed in November.)
19. Grain sorghum. (Plowed in July.)

Field B5

1. Corn. (Plowed in July.)
2. Corn, manure. (Plowed in July.)
3. Cotton. (Plowed in November.)
4. Cotton, manure. (Plowed in November.)
5. Sorghum, 4.1-foot rows. (Plowed in November.)
6. Sorghum, 8-inch drills. (Plowed in November.)

Plot No.

7. Oats for hay. (Plowed in May.)
8. Oats for grain. (Plowed in October.)

Rotation A

9. Cotton. (Plowed in November.)
10. Sorghum, 4.1-foot rows. (Plowed in November.)

Rotation B

11. Cotton. (Plowed in November.)
12. Sorghum, 8-inch drills. (Plowed in November.)

Rotation C

13. Corn. (Plowed in July.)
14. Sorghum, drills 4.1 feet apart. (Plowed in November.)

Rotation D

15. Corn. (Plowed in July.)
16. Sorghum, 8-inch drills. (Plowed in November.)

Rotation E

17. Grain sorghum. (Plowed in July.)
18. Cotton. (Plowed in November.)

FIELD B6

Rotation A

1. Corn. (Plowed in July.)
2. Cotton. (Plowed in November.)

Rotation B

3. Corn. (Plowed and subsoiled in July.)

Plot No.

4. Cotton. (Plowed and subsoiled in November.)

Rotation C

5. Corn, manured. (Plowed in July.)
6. Cotton. (Plowed in November.)

Rotation D

7. Corn, manure, field peas. (Plowed under in spring.)
8. Cotton. (Plowed in November.)

Rotation E

9. Corn, manure, field peas. (Plowed under in spring.)
10. Cotton. (Plowed and subsoiled in November.)

Rotation F

11. Corn. (Disked in July.)
12. Cotton. (Plowed in November.)

Rotation G

13. Corn. (Plowed in February.)
14. Cotton. (Plowed in February.)

Rotation H

15. Corn. (Plowed and subsoiled in February.)
16. Cotton. (Plowed and subsoiled in February.)

Rotation I

17. Corn, disked in rye. (Plowed in February.)
18. Cotton. (Plowed in November.)

CULTURAL PRACTICES

Cultural practices were carried out as uniformly as possible on plots scheduled to be treated the same. Plots were plowed to a depth of about 7 inches with a reversible disk plow, throwing all the soil one way. Where subsoiling was practiced the subsoil plow was run in the furrow behind the disk plow, loosening the soil to an additional depth of 6 to 8 inches. Manure, when it appears in the rotation, was applied at the rate of 16 tons per acre and plowed under. Where a green-manure crop was grown following oats or corn, the ground was thoroughly disked in order to prepare a good seed bed, and the crop was drilled in. This made it unnecessary to plow any plot twice during a season. The plots were kept free of weeds during the interval between plowing and the subsequent crop by cultivation with a disk harrow or an orchard cultivator. In order that plots of the same crop might be comparable, all plots were planted and harvested under as nearly the same conditions as possible. The same variety of a crop was used in all rotations and throughout the period of the experiment, except in a few cases where improved varieties were substituted.

At various times it was impossible to carry on practices uniformly, because of weather and other conditions. Other factors, such as birds, plant diseases, and insects, at times influenced the results, sometimes uniformly throughout all rotations and at other times more seriously in some rotations than in others. In most instances it was impossible to make corrections for such disturbing factors. Where such conditions definitely depressed yields they are noted in the text. The cotton root-rot disease, which is prevalent at the San Antonio station, was at times a factor of importance in influencing the yield of cotton. For years records have been kept of the occurrence of the disease and the effect of various rotational practices on its occurrence (*11, 12, 13*).[1]

CROP YIELDS IN DETAIL

In order to present in detail the results of the experiments and to permit comparison in a number of different ways, a table is given for each crop, showing the data recorded. The yields per acre are given for each rotation for each year. Maximum, minimum, and mean yields are also indicated for each year. The mean yield of each rotation for the entire period of the experiment is presented, and in addition the mean yield for the last 10 years is presented and compared with the first 11 years of the experiment where possible.

OATS

The yields of oats are given in Table 3. The variety chiefly grown was Texas Rustproof. There were 16 rotations in which oats were grown. In 8 of these the crop was harvested for hay, and in the remainder the crop was allowed to mature grain. Of the rotations including oats cropped for hay, only 4 were started in 1909; the others were added in 1913. Of those rotations in which oats were harvested for grain 5 were started in 1909, 1 in 1910, and the other 2 in 1913. In addition to periodical droughts, an important factor in oat production in the San Antonio region is that of the plant diseases, stem rust and leaf rust. The reaction of the diseases in these rotations will be discussed more fully later. There were numerous failures or near failures during the period of the experiment. The mean yields of grain and hay were low. The maximum yield of grain for any year was 74.3 bushels per acre, and the highest mean yield was 56.6 bushels per acre. There were several instances of complete failure. While the oats harvested for hay, with one exception, produced a crop every year, the tonnage was small in many cases. The maximum yield of hay was 3.79 tons per acre and the highest mean yield 3.31 tons per acre. Mean yields of grain increased during the last 10-year period of the experiment, while hay yields remained very nearly stationary. The station was closed from July 1, 1920, to March 1, 1921, because of lack of funds. As a result no small grains were planted for the 1921 season. In 1925 a severe drought caused complete failure of all oats.

---

[1] Italic numbers in parentheses refer to Literature Cited, p. 39.

TABLE 3.—*Acre yields of oats at the San Antonio field station, 1909–1929*

HARVESTED FOR GRAIN (BUSHELS)

Rotation	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920
A4-C	------	4.1	10.1	37.0	38.0	16.5	30.4	9.5	9.6	28.6	52.1	24.7
A4-F	------	------	------	------	5.0	24.8	20.4	2.6	3.3	7.3	48.5	25.3
A4-G	------	------	------	------	6.9	23.1	24.5	1.6	3.4	8.9	53.6	29.1
A5-C	0	4.2	7.8	31.7	7.4	13.1	16.7	2.9	4.4	11.7	55.7	29.6
A5-D	0	5.1	5.4	24.1	7.5	13.0	15.3	2.8	3.6	11.2	28.1	28.7
A5-E	0	3.8	6.2	25.0	6.3	18.1	13.5	3.1	4.5	12.9	23.4	25.9
A6-E	0	19.8	7.7	22.4	11.4	4.3	9.7	9.8	15.0	16.2	27.8	13.3
B5-8	0	4.7	6.3	20.4	10.3	12.6	25.1	3.6	8.9	6.3	52.9	36.1
Maximum	0	19.8	10.1	37.0	38.0	24.8	30.4	9.8	15.0	28.6	55.7	36.1
Minimum	0	3.8	5.4	20.4	5.0	4.3	9.7	1.6	3.3	6.3	23.4	13.3
Mean	0	7.0	7.3	26.8	11.6	15.7	19.5	4.5	6.6	14.1	42.8	26.6

Rotation	1921 [1]	1922	1923	1924	1925 [2]	1926	1927	1928	1929	Mean		
										Period grown	1909–1919	1920–1929 [1]
A4-C	------	14.6	37.3	62.1	0	60.0	20.1	15.9	25.1	26.1	23.6	28.9
A4-F	------	3.1	50.5	71.5	0	56.6	0	0	21.5	21.3	16.0	25.4
A4-G	------	4.0	42.0	72.4	0	52.1	0	0	22.0	21.5	17.4	24.6
A5-C	------	6.5	51.9	72.1	0	62.0	0	0	16.9	19.7	14.1	26.6
A5-D	------	3.0	25.5	36.4	0	30.4	0	0	9.1	12.5	10.6	14.8
A5-E	------	2.4	18.4	29.9	0	38.6	0	0	7.9	12.0	10.6	13.7
A6-E	------	5.4	20.0	34.1	0	39.9	0	0	8.5	13.8	14.0	13.5
B5-8	------	11.9	43.6	74.3	0	53.8	2.9	0	23.5	19.9	13.7	27.3
Maximum	------	14.6	51.9	74.3	0	62.0	20.1	15.9	25.1	------	------	------
Minimum	------	2.4	18.4	29.9	0	30.4	0	0	7.9	------	------	------
Mean	------	6.4	36.2	56.6	0	49.2	2.9	2.0	16.8	17.6	14.2	21.9

HARVESTED FOR HAY (TONS)

Rotation	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920
A5-A	------	------	------	------	2.30	1.88	2.15	0.55	0.59	1.52	3.13	2.02
A5-B	------	------	------	------	2.29	1.64	2.24	.63	.65	1.87	2.11	2.27
A6-1A	0.16	0.68	1.53	3.09	3.14	2.20	2.35	1.62	1.68	1.44	3.74	2.02
A6-A	.24	1.03	1.53	2.78	3.57	1.17	2.35	1.29	1.64	1.64	3.79	2.10
A6-B	------	------	------	------	3.20	1.06	2.31	1.34	1.15	1.95	3.73	2.14
A6-C	.13	1.17	------	2.53	3.05	.90	2.10	.86	1.05	1.92	3.61	2.07
B4-B	------	------	------	------	1.36	1.02	2.12	.66	.70	1.89	3.49	2.29
B5-7	0	.64	1.30	2.87	2.47	.78	2.12	1.30	.74	1.33	2.86	2.47
Maximum	.24	1.17	1.53	3.09	3.57	2.20	2.35	1.62	1.68	1.95	3.79	2.47
Minimum	0	.64	1.30	2.53	1.36	.78	2.10	.55	.59	1.33	2.11	2.02
Mean	.13	.88	1.45	2.82	2.67	1.33	2.22	1.03	1.03	1.70	3.31	2.17

Rotation	1921 [1]	1922	1923	1924	1925 [2]	1926	1927	1928	1929	Mean		
										Period grown	1909–1919	1920–1929
A5-A	------	1.12	2.29	2.74	0	2.72	0.80	0.73	1.32	1.62	1.73	1.53
A5-B	------	1.21	1.70	1.78	0	2.29	.65	.98	1.34	1.48	1.63	1.36
A6-1A	------	1.65	2.68	3.27	0	2.72	1.19	.69	1.38	1.86	1.97	1.73
A6-A	------	1.40	2.61	2.80	0	2.98	1.45	1.00	1.88	1.86	1.91	1.80
A6-B	------	1.39	2.48	3.04	0	2.78	1.14	.79	1.71	1.89	2.11	1.72
A6-C	------	1.46	2.54	3.24	0	2.71	1.52	.71	1.56	1.74	1.73	1.76
B4-B	------	1.27	2.44	2.79	0	2.76	.76	.93	1.63	1.63	1.61	1.65
B5-7	------	1.53	2.42	2.02	0	2.68	1.84	1.42	1.34	1.61	1.49	1.75
Maximum	------	1.65	2.68	3.27	0	2.98	1.84	1.42	1.88	------	------	------
Minimum	------	1.12	1.70	1.78	0	2.29	.65	.69	1.32	------	------	------
Mean	------	1.38	2.40	2.71	0	2.71	1.17	.91	1.52	1.68	1.69	1.66

---

[1] Station was closed from July 1, 1920, to Mar. 1, 1921, because of lack of funds.
[2] A severe drought caused complete failure of all oats.

CORN

The yields of corn are given in Table 4. There were 19 rotations that included corn in the crop sequence, and 2 plots were continuously cropped. One of the latter received manure every year, while the other was untreated. The mean yield for the 21-year period was 28.0 bushels per acre. The largest annual mean yield of 52.6 bushels per acre was obtained in 1914. A 2-year rotation of corn following oats plowed in May produced the highest yield of corn. Although grain sorghum is often recommended for this section, corn yielded 6.3 bushels per acre more than milo for the years in which both were grown. The yields of milo were somewhat depressed, as grown under the experimental conditions at the station, through destruction of part of the crop by birds and by the sorghum midge. The losses from birds would doubtless be greatly reduced were larger acreages grown.

TABLE 4.—*Acre yields of corn (bushels), at the San Antonio field station, 1909–1929*

Rotation	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920
A4-B	-------	2.6	3.2	24.7	30.7	29.4	15.3	15.5	11.6	28.5	43.4	38.6
A4-D	-------	-------	2.7	25.3	26.9	35.2	20.9	1.4	4.5	21.9	43.2	43.9
A6-A	9.3	14.0	18.2	42.3	40.3	56.2	41.1	33.5	13.8	28.5	49.4	54.0
A6-B	5.2	12.3	8.0	42.0	35.7	43.1	31.1	3.9	11.2	11.8	54.6	43.7
A6-C	4.4	7.4	16.9	42.2	38.1	51.3	36.6	29.6	10.7	15.6	51.7	50.6
A6-D	.8	4.6	16.3	39.8	36.9	47.7	30.2	12.6	16.2	12.7	52.6	42.3
A6-E	2.4	8.0	19.6	36.3	39.5	48.6	30.3	22.4	17.8	30.1	45.4	47.4
A6-F	1.1	11.0	17.7	36.7	37.4	53.0	25.6	3.7	16.7	14.2	49.7	45.4
B5-1	1.1	3.3	5.4	26.6	33.1	43.2	27.2	11.5	11.9	16.6	52.0	51.1
B5-2	9.1	4.7	12.6	30.5	31.7	48.3	30.9	13.3	13.3	28.6	44.9	51.4
B5-C	.5	4.1	5.6	27.7	34.1	50.4	21.5	4.0	4.8	13.9	49.4	46.3
B5-D	.9	5.7	5.4	29.0	33.4	58.3	20.6	2.3	4.6	12.8	47.7	48.9
B6-A	17.5	8.3	13.3	41.8	36.6	73.1	27.9	1.9	7.1	12.8	50.9	66.3
B6-B	18.9	6.9	11.7	37.4	39.5	63.7	29.9	4.3	9.0	17.6	50.9	62.0
B6-C	19.1	9.4	14.8	42.3	31.0	69.3	39.8	2.4	7.9	14.1	45.4	64.0
B6-D	19.4	12.1	11.8	39.7	33.4	70.2	39.8	2.1	8.2	10.1	44.9	61.7
B6-E	23.1	8.6	14.6	38.7	35.8	61.6	43.6	2.5	11.6	10.6	46.9	51.4
B6-F	28.2	11.1	11.5	37.5	37.2	55.9	33.6	5.5	9.8	13.1	54.0	48.6
B6-G	22.8	16.0	11.6	35.2	35.8	48.1	30.3	2.5	10.6	15.7	50.9	45.1
B6-H	27.6	8.9	10.6	34.1	33.3	45.9	28.1	2.5	13.4	16.0	50.6	36.6
B6-I	27.2	7.9	11.4	36.2	32.0	52.3	32.6	1.9	9.0	31.2	48.9	42.9
Maximum	28.2	16.0	19.6	42.3	40.3	73.1	43.6	33.5	17.8	31.2	54.6	66.3
Minimum	.5	2.6	2.7	24.7	26.9	29.4	15.3	1.4	4.5	10.1	43.2	36.6
Mean	12.6	8.3	11.6	35.5	34.9	52.6	30.3	8.5	10.7	17.9	48.9	49.6

Rotation	1921	1922	1923	1924	1925	1926	1927	1928	1929	Mean		
										Period grown	1909–1919	1920–1929
A4-B	28.6	35.0	19.1	38.0	0	38.1	22.7	11.5	38.3	23.7	20.5	27.0
A4-D	18.8	35.3	25.3	41.6	0	40.3	8.8	15.6	48.1	24.2	20.2	27.8
A6-A	43.7	45.4	37.2	46.8	.6	43.9	23.9	12.1	36.7	32.9	31.5	34.4
A6-B	39.2	42.2	29.4	51.6	0	44.9	8.3	13.7	33.8	26.9	23.5	30.7
A6-C	39.6	43.8	35.4	44.4	3.2	46.5	20.1	16.0	45.6	30.9	27.7	34.5
A6-D	37.4	40.7	31.2	47.6	0	41.8	11.9	20.2	41.7	27.9	24.6	31.5
A6-E	32.6	36.4	30.6	57.3	.6	35.5	21.1	22.4	45.6	30.0	27.3	33.0
A6-F	47.2	49.9	28.8	57.3	0	38.2	14.5	20.5	45.9	29.3	24.3	34.8
B5-1	25.5	35.6	24.6	49.8	0	37.2	8.0	11.9	32.7	24.2	21.1	27.6
B5-2	15.9	37.0	18.5	51.4	0	35.9	7.4	8.9	28.6	24.9	24.4	25.5
B5-C	35.3	26.4	29.0	40.0	0	38.1	14.3	9.6	33.8	23.3	19.6	27.3
B5-D	27.3	21.9	31.2	41.9	0	36.3	14.1	10.3	35.9	23.3	20.1	26.8
B6-A	20.2	36.8	37.2	60.0	0	47.9	15.7	16.4	42.6	30.2	26.5	34.3
B6-B	27.4	41.0	35.4	53.5	0	44.0	19.9	17.3	46.0	30.3	26.3	34.7
B6-C	16.0	40.8	35.6	63.9	0	43.2	13.4	16.3	42.9	30.1	26.9	33.6
B6-D	19.2	42.1	38.4	60.8	0	41.1	16.3	16.4	37.3	29.8	26.5	33.3
B6-E	24.0	41.9	39.7	59.1	.4	43.6	17.5	18.5	44.3	30.4	27.1	34.0
B6-F	25.0	42.9	38.6	55.9	0	45.2	13.0	15.5	43.8	29.8	27.0	32.9
B6-G	32.6	42.4	33.7	51.6	0	40.0	18.5	19.5	44.9	28.9	25.4	32.8
B6-H	36.6	43.7	33.3	49.6	0	40.6	18.8	24.6	42.1	28.4	24.6	32.6
B6-I	35.2	47.6	32.0	54.1	0	39.8	17.4	26.1	46.2	30.1	26.4	34.1
Maximum	47.2	49.9	39.7	63.9	3.2	47.9	23.9	26.1	48.1	-------	-------	-------
Minimum	15.9	21.9	18.5	38.0	0	35.5	7.4	8.9	28.6	-------	-------	-------
Mean	29.9	39.5	31.6	51.2	.2	41.1	15.5	16.3	40.8	28.0	24.7	31.6

MILO

Table 5 gives the detailed data for milo. This crop was first introduced in the experiment in five plots in 1912, while in 1913 the remaining nine plots were added. During the first seven years that milo was grown the yield per acre was in excess of corn and also much better than during the last 10 years. The mean of 24.6 bushels per acre for the 18-year period is somewhat below the yield of corn. The highest yield of milo was produced in 1913, when the maximum of 57.3 bushels and a mean of 47.7 bushels per acre were obtained. A 4-year rotation of milo, cotton, oats followed by cowpeas for green manure, and cotton produced the highest mean. The lowest yields were produced by the untreated continuously cropped plot. There have been two complete failures of milo in the last 10 years of the experiment. In 1920 the sorghum midge (*Contarinia sorghicola* Coq.) (*1*, *2*) was the cause of complete failure. In 1925 milo as well as most other crops was a complete failure because of drought. Birds also are a great menace to the sorghum crop in this section, especially when the sorghum is planted in small plots under experimental conditions. Since the damage was not uniform on the various plots, the yields of milo were not as dependable as desired. It is evident that the mean yield would have been higher had it not been for these factors.

TABLE 5.—*Acre yields of milo (bushels) at the San Antonio field station, 1912–1929*

Rotation	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922
A4–F	------	49.2	51.9	21.6	14.9	13.5	20.9	23.3	0	29.2	19.6
A4–G	------	44.3	44.0	23.3	19.1	22.9	19.2	30.2	0	31.3	21.6
A5–A	------	48.8	44.5	25.9	2.4	15.6	16.6	36.1	0	27.4	27.8
A5–B	------	50.6	52.6	30.9	3.7	19.9	20.1	47.1	0	32.7	37.1
A5–C	------	46.8	47.6	33.7	4.6	25.2	18.9	34.0	0	36.3	26.4
A5–D	------	49.8	49.1	39.7	4.4	24.8	24.1	44.0	0	28.5	34.7
A5–E	------	52.8	30.9	29.6	6.5	20.0	24.4	45.4	0	33.7	24.5
A6–1	32.5	36.2	9.7	15.9	10.9	14.4	20.6	17.4	0	27.2	17.7
A6–2	52 0	47.6	43.3	26.4	11.9	12.3	35.2	37.2	0	44.0	30.0
A6–1A	32.5	42.0	28.6	16.4	11.3	22.1	27.9	20.1	0	27.9	15.9
A6–D	46.5	41.7	28.1	5.4	12.0	25.9	26.4	21.6	0	29.6	17.6
B4–A	------	54.1	39.5	18.1	3.7	10.9	11.2	21.7	0	26.8	16.8
B4–B	------	57.3	46.0	21.4	3.7	24.6	19.4	24.9	0	40.3	20.9
B5–E	36.4	46.1	29.9	11.1	2.5	18.1	13.9	26.5	0	26.9	15.4
Maximum	52.0	57.3	52.6	39.7	19.1	25.9	35.2	47.1	0	44.0	37.1
Minimum	32.5	36.2	9.7	5.4	2.4	10.9	11.2	17.4	0	26.8	15.4
Mean	40.0	47.7	39.0	22.8	8.0	19.3	21.3	30.7	0	31.6	23.3

Rotation	1923	1924	1925	1926	1927	1928	1929	Mean		
								Period grown	1912–1919	1920–1929
A4–F	41.4	22.3	0	38.3	19.4	16.7	40.0	24.8	27.9	22.7
A4–G	44.1	25.1	0	32.7	25.5	20.1	30.4	25.5	29.0	23.1
A5–A	45.6	29.4	0	32.3	18.1	19.9	31.8	24.8	27.1	23.2
A5–B	31.7	39.6	0	28.6	21.4	18.2	29.1	27.3	32.1	23.8
A5–C	45.6	29.1	0	33.6	18.5	19.4	41.6	27.1	30.1	25.1
A5–D	50.9	34.5	0	36.9	19.3	21.6	34.0	29.2	33.7	26.0
A5–E	50.0	32.3	0	39.4	22.7	23.4	19.6	26.8	29.9	24.6
A6–1	32.9	7.9	0	24.4	14.3	9.9	10.2	16.8	19.7	14.5
A6–2	43.1	23.0	0	20.6	0	2.9	7.9	24.3	33.2	17.2
A6–1A	35.0	5.1	0	26.3	26.4	12.5	19.1	20.5	25.1	16.8
A6–D	37.9	2.0	0	23.7	18.1	19.3	18.9	20.8	26.0	16.7
B4–A	39.7	30.9	0	38.9	17.4	15.7	29.9	22.1	22.7	21.6
B4–B	42.4	23.5	0	24.6	18.2	18.0	37.3	24.9	28.2	22.5
B5–E	48.8	22.4	0	25.3	17.9	14.3	18.1	20.8	23.1	18.9
Maximum	50.9	39.6	0	39.4	26.4	23.4	41.6	------	------	------
Minimum	31.7	2.0	0	20.6	14.3	2.9	7.9	------	------	------
Mean	42.1	23.4	0	30.4	18.4	16.6	26.3	24.5	28.6	21.2

SORGHUM

In Table 6 are given the detailed yields for forage sorghum. The Sumac variety was used. In 5 rotations the sorghum was grown in rows; 4 of these were started in 1909 and 1 in 1911. In the remaining

Table 6.—*Acre yields of sorghum (tons) for forage at the San Antonio field station, 1909–1929*

IN 4.1-FOOT ROWS

Rotation	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	Mean		
																						Period grown	1909–1919	1920–1929
A4-E	-------	-------	2.12	3.82	7.11	4.50	5.15	5.37	2.74	5.20	8.35	2.84	5.09	4.45	4.15	3.82	1.47	3.01	3.46	2.54	4.52	4.20	4.93	3.54
A6-4	2.10	3.01	2.88	3.04	4.50	6.10	4.75	2.80	1.96	2.44	6.09	3.56	4.59	3.36	3.04	3.94	.23	2.59	2.24	1.92	3.13	3.26	3.69	2.78
B5-5	1.39	2.48	3.66	4.05	6.72	6.50	5.23	3.17	2.51	3.88	7.13	3.18	5.48	4.06	3.30	3.18	.32	3.33	3.16	3.76	3.74	3.82	4.25	3.35
B5-A	1.49	2.98	3.83	4.08	7.35	7.40	5.36	3.37	2.22	3.10	7.49	5.34	4.98	4.24	4.72	4.77	.26	3.92	2.75	2.81	4.96	4.16	4.42	3.88
B5-C	1.75	3.76	3.37	4.28	7.78	7.80	6.09	4.86	3.38	4.34	7.37	5.23	6.47	5.16	4.33	3.95	1.51	3.51	2.99	2.46	3.57	4.47	4.98	3.92
Maximum	2.10	3.76	3.83	4.28	7.78	7.80	6.09	5.37	3.38	5.20	8.35	5.34	6.47	5.16	4.72	4.77	1.51	3.92	3.46	3.76	4.96	-------	-------	-------
Minimum	1.39	2.48	2.12	3.82	4.50	4.50	4.75	2.80	1.96	2.44	6.09	2.84	4.59	3.36	3.04	3.14	.23	2.59	2.24	1.92	3.13	-------	-------	-------
Mean	1.68	3.06	3.17	4.03	6.69	6.46	5.32	3.91	2.56	3.79	7.29	4.03	5.32	4.25	3.91	3.77	.76	3.27	2.92	2.70	3.98	3.95	4.36	3.49

IN 8-INCH DRILLS

Rotation	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	Mean		
																						Period grown	1909–1919	1920–1929
A4-F	-------	-------	-------	-------	5.98	10.9	7.19	4.17	2.00	1.80	9.03	5.59	3.85	4.08	3.60	6.03	0	3.68	3.41	2.35	4.36	4.59	5.87	3.70
A4-G	-------	-------	-------	-------	5.67	10.4	4.21	4.73	2.19	1.65	9.41	6.53	4.84	2.76	2.62	6.43	0	3.64	3.29	3.22	3.72	4.43	5.47	3.71
B4-12	-------	-------	-------	-------	-------	9.9	9.15	2.46	1.78	1.57	8.65	10.52	7.97	5.13	5.18	4.77	0	3.69	4.18	3.62	6.11	5.29	5.59	5.12
B4-13	-------	-------	-------	-------	6.92	10.0	7.59	2.22	1.80	1.51	8.76	9.69	5.52	4.03	3.92	4.61	0	3.28	3.82	4.63	5.29	4.92	5.54	4.48
B5-6	1.20	0.43	4.28	4.16	4.00	8.7	5.52	1.72	1.27	1.81	6.72	3.62	2.89	2.68	2.64	2.62	0	4.08	3.74	4.05	4.28	3.35	3.62	3.06
B5-B	1.23	.80	3.93	4.39	7.32	11.0	7.54	2.21	2.01	2.38	9.58	11.84	3.99	6.07	5.39	6.18	0	4.25	4.37	4.22	6.23	5.00	4.76	5.25
B5-D	.78	.98	4.86	5.50	7.35	10.9	9.33	6.60	3.60	4.95	9.08	11.82	6.07	5.91	4.60	6.31	1.91	3.68	3.17	4.61	4.46	5.55	5.81	5.25
Maximum	1.23	.98	4.86	5.50	7.35	11.0	9.33	6.60	3.60	4.95	9.58	11.84	7.97	6.07	5.39	6.43	1.91	4.25	4.37	4.63	6.23	-------	-------	-------
Minimum	.78	.43	3.93	4.16	4.00	8.7	4.21	1.72	1.27	1.51	6.72	3.62	2.89	2.68	2.62	2.62	0	3.28	3.17	2.35	3.72	-------	-------	-------
Mean	1.07	.74	4.36	4.68	6.21	10.26	7.22	3.44	2.09	2.24	8.75	8.52	5.02	4.38	3.99	5.28	.27	3.76	3.71	3.81	4.92	4.51	4.64	4.37

7 rotations the sorghum was grown in 8-inch drills. Three of these were started in 1909, 3 in 1913, and 1 in 1914. Sorghum grown in drills produced on the average 0.56 ton per acre per year more than that grown in rows. The quality of the hay was also superior. Planting in rows is the standard method when it is desired to use the crop for silage. The highest yield of hay produced when grown in rows was 8.35 tons per acre, while the highest yield produced when grown in drills was 11.84 tons per acre. No complete failures occurred, but the yields were very low in 1925. The highest yields of sorghum both in rows and in drills were produced in 2-year rotations of corn and sorghum. Sorghum seems to respond to improved treatment, and the differences in yield are apparently significant.

SUDAN GRASS

Table 7 gives the yield data for Sudan grass. This crop was introduced with rotation B4–A in 1913 and substituted for oats in A6–F in 1914. The mean yield of Sudan grass was higher than that of sorghum, although the maximum yield, 8.88 tons per acre, was not as high as the maximum yield of sorghum. The quality of hay of Sudan grass was superior to that of sorghum. As there were only two rotations in which Sudan grass was grown, and as these were located some distance apart, comparisons are not warranted.

TABLE 7.—*Acre yields of Sudan grass (tons) at the San Antonio field station, 1913–1929*

Rotation	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922
A6–F	------	8.20	6.48	4.49	4.20	5.09	8.88	5.34	8.50	5.63
B4–A	5.30	7.20	6.00	4.27	2.07	2.70	7.90	6.92	6.24	3.55
Mean	5.30	7.70	6.24	4.38	3.14	3.90	8.39	6.13	7.37	4.59

Rotation	1923	1924	1925	1926	1927	1928	1929	Mean		
								Period grown	1913–1919	1920–1929
A6–F	5.[illegible]	5.66	1.57	4.74	3.89	5.55	4.35	5.52	6.22	5.09
B4–A	3.82	5.20	0	2.95	2.65	2.20	4.87	4.34	5.06	3.84
Mean	4.77	5.43	.79	3.85	3.27	3.88	4.61	4.93	5.58	4.47

COTTON

Table 8 gives the yields of cotton.

Cotton is the principal cash crop of the region, but yields at the station have been very low especially in recent years. The mean production for 1925 was only 73 pounds of seed cotton per acre, no yields being harvested from seven of the plots that season; for 1927 the yield was but little better than a failure; and for 1928 and 1929 the crop was a total failure. From a practical standpoint the crop

TABLE 8.—*Acre yields of seed cotton (pounds) at the San Antonio field station, 1909–1929*

Rotation	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920
A4-A	------	252	318	448	350	412	500	364	388	318	8	80
A4-D	------	------	323	510	500	513	520	463	538	395	43	196
A4-F	------	------	------	------	494	590	552	356	460	122	44	252
A4-G	------	------	------	------	582	582	582	290	468	114	58	240
A4-19	------	------	------	------	666	632	404	230	360	120	58	256
A5-A	536	340	600	554	596	728	638	674	600	194	44	392
A5-B	580	312	387	600	522	716	578	826	648	222	70	544
A5-C1	424	332	550	570	446	598	616	816	518	126	64	396
A5-C2	386	342	567	486	484	564	514	566	624	212	36	476
A5-D1	426	310	502	650	500	668	620	680	488	174	104	640
A5-D2	454	376	536	616	578	636	534	646	524	220	108	600
A5-E1	604	378	444	488	600	740	604	568	538	214	102	620
A5-E2	392	338	610	630	706	674	622	618	556	250	110	576
A6-3	854	360	468	696	632	964	414	260	452	138	76	492
B4-A	------	------	------	------	632	820	648	256	434	162	62	316
B4-B	------	------	------	------	666	638	758	426	582	306	78	272
B5-3	838	272	446	474	508	724	440	260	494	164	32	272
B5-4	516	286	508	572	554	768	550	242	682	360	32	344
B5-A	734	268	498	542	398	650	532	332	610	160	6	528
B5-B	552	222	410	542	448	708	420	246	574	148	6	548
B5-E	364	400	498	620	594	998	518	368	454	202	4	476
B6-A	870	501	458	726	640	918	528	372	592	390	6	572
B6-B	832	344	420	740	564	1,024	516	370	630	380	12	436
B6-C	564	448	524	692	760	1,444	578	698	682	584	16	740
B6-D	694	482	560	800	614	1,434	836	526	764	496	8	664
B6-E	774	556	556	818	572	1,388	768	490	686	492	12	516
B6-F	928	488	596	676	710	802	696	398	784	410	18	396
B6-G	814	464	480	780	604	760	464	288	468	254	14	396
B6-H	784	372	422	712	448	728	454	202	450	172	14	368
B6-I	794	466	394	596	436	690	600	72	20	260	22	344
Maximum	928	556	610	818	760	1,444	836	826	784	584	110	740
Minimum	364	222	318	448	350	412	404	72	20	114	4	80
Mean	640	371	483	622	560	784	567	430	536	259	42	432

Rotation	1921	1922	1923	1924	1925	1926	1927	1928	1929	Mean		
										Period grown	1909–1919	1920–1929
A4-A	170	47	324	110	0	205	1	0	0	215	336	94
A4-D	465	126	468	235	0	245	4	0	0	292	423	174
A4-F	448	137	437	326	0	302	7	0	0	266	374	191
A4-G	469	235	498	266	0	386	8	0	0	281	382	210
A4-19	224	208	432	271	10	388	7	0	0	251	353	180
A5-A	589	183	547	332	213	465	17	0	0	392	500	274
A5-B	614	293	538	351	136	472	22	0	0	401	496	297
A5-C1	541	245	537	229	142	392	18	0	0	360	460	250
A5-C2	600	296	553	215	29	474	17	0	0	354	435	266
A5-D1	497	301	547	282	15	498	17	0	0	377	466	280
A5-D2	714	275	363	308	14	558	24	0	0	385	475	286
A5-E1	630	184	546	268	20	514	18	0	0	385	480	280
A5-E2	844	248	344	304	20	508	20	0	0	399	501	286
A6-3	360	203	286	256	18	422	8	0	0	350	483	205
B4-A	382	173	639	216	0	438	10	0	0	305	431	217
B4-B	591	379	681	308	36	484	21	0	0	366	493	277
B5-3	273	253	404	280	5	327	2	0	0	308	423	182
B5-4	159	431	233	358	5	550	11	0	0	341	461	209
B5-A	476	228	775	374	0	472	15	0	0	362	430	287
B5-B	329	250	689	370	0	522	21	0	0	334	389	273
B5-E	443	171	404	244	20	272	13	0	0	336	456	204
B6-A	529	170	588	325	78	542	12	0	0	420	546	282
B6-B	478	175	347	234	190	542	4	0	0	392	530	241
B6-C	869	338	704	447	263	568	28	0	0	521	635	396
B6-D	842	279	751	589	380	474	31	0	0	534	656	401
B6-E	684	254	836	612	174	434	28	0	0	507	647	354
B6-F	509	332	672	328	32	476	21	0	0	442	591	277
B6-G	441	338	624	229	90	402	20	0	0	378	490	254
B6-H	472	395	674	331	102	456	22	0	0	361	433	282
B6-I	480	266	383	295	210	390	19	0	0	321	395	239
Maximum	869	431	836	612	380	568	31	0	0	------	------	------
Minimum	159	47	233	110	0	205	1	0	0	------	------	------
Mean	504	247	527	310	73	439	16	0	0	373	481	255

has been a failure for the last five years of the experiment (1925–1929). Drought caused a very low yield in 1925. Early-season prospects were good in 1927 but serious damage by angular leaf spot and a heavy infestation of boll weevils, induced by a very wet June, followed by an intense drought, caused nearly complete loss of the crop. In June of 1928 a very localized hailstorm completely destroyed the cotton plants when it was too late to replant. Severe boll-weevil injury prevented the production of measurable yields of cotton in 1929, although good plant growth was produced. Because of these adverse seasons the yields of cotton from 1920 to 1929 showed a marked decrease from the first period (1909–1919).

There were 26 rotations that included cotton, and there were four continuously cropped plots. Of these, all except seven were started in 1909. One was added in 1910, one in 1911, and the other five in 1913. The highest mean yield for all plots was 784 pounds of seed cotton per acre in 1914 with a maximum yield of 1,444 pounds for a single plot. There was a wide range in the yields of the various rotations, undoubtedly owing in part to plot variation. The range in degree of the infestation of the different plots by cotton root rot (*Phymatotrichum omnivorum* (Shear) Duggar) was also responsible for many variations in yield. No satisfactory method of correlating the degree of root-rot injury with reduction of yield has been discovered.

SEASONAL FLUCTUATION IN YIELD

During the period covered by these experiments there were numerous disturbing factors affecting crop production. In some instances these factors affected all crops uniformly, but usually there were differences in the degree of influence due to conditions and the stage of maturity of the crops. Seasonal conditions were very erratic and influenced the crops differently. The growing season at the station extends over practically the entire year; and while conditions may be favorable for a winter and early summer crop like oats, the remainder of the season may be adverse for late-season crops such as cotton and forage sorghum. These conditions are quite different from those encountered where all crops are grown more nearly at the same time.

In order to indicate to some extent the seasonal variation in yields, Table 9 is included, in which the mean annual yield for each crop is expressed as a percentage of the mean yield of that crop for the 21-year period 1909 to 1929. The mean percentage of all crops is also given, but because of the variations in growing conditions and other disturbing influences, such as insects and plant diseases, the significance of this is limited.

TABLE 9.—*Mean annual yield of each crop in the rotations expressed as a percentage of the mean yield of that crop for the 21-year period 1909–1929, at the San Antonio field station*

Year	Oats for—		Corn	Cotton	Milo	Sorghum grown in—		Sudan grass	Mean
	Grain	Hay				4.1-foot rows	8-inch drills		
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1909	0	8	45	172	--------	43	24	--------	49
1910	40	52	30	99	--------	77	16	--------	52
1911	41	86	41	129	--------	80	97	--------	79
1912	152	168	127	167	163	102	104	--------	140
1913	66	159	125	150	195	169	138	108	139
1914	89	79	188	210	159	164	227	156	159
1915	111	132	108	152	93	135	160	127	127
1916	26	61	30	115	33	99	76	89	66
1917	38	61	38	144	79	65	46	64	67
1918	80	101	64	69	87	96	50	79	78
1919	243	197	175	11	125	185	194	170	163
1920	151	129	177	116	0	102	189	124	124
1921	--------	--------	107	135	129	135	111	149	128
1922	36	82	141	66	95	108	97	93	90
1923	206	143	113	141	172	99	88	97	132
1924	322	161	183	83	95	95	117	110	146
1925	0	0	1	20	0	19	6	16	8
1926	280	161	147	118	124	83	83	78	134
1927	16	70	55	4	75	74	82	66	55
1928	11	54	58	0	67	68	84	79	53
1929	95	90	146	0	107	101	109	94	93

Table 9 shows the effect of erratic seasonal conditions on the production of oats. Expressed as percentages, the mean annual yields under the conditions ranged from zero or near zero in several instances to a maximum of 322 in 1924. This was due in part to variations in rainfall and in part to the influence of stem rust and leaf rust. Conditions for the production of corn were more consistent than those for oats. The yields of corn have been satisfactory in recent years. Milo produced very well during the earlier years, but recent yields have not been so satisfactory. Birds and the sorghum midge are important limiting factors in milo production. Rainfall is largely the limiting factor in connection with the production of sorghum for forage. No insects or plant diseases influence the yield materially. The yields have fluctuated from near zero to about 10 tons per acre. Conditions for cotton production have been very erratic, especially in recent years. Diseases and insects are very important factors in connection with the successful production of this crop. Hail injury in 1928, when the plants were small, caused a total crop failure that year. This storm also damaged other crops severely, but none so much as cotton.

COMPARISON OF EFFECTS OF ROTATIONS AND CULTURAL TREATMENTS ON CROP YIELDS

In the following discussion the effect of the various rotational and cultural practices upon each crop is considered. In order to facilitate these comparisons a table is given for each crop, in which rotations are grouped according to treatment. The information given for each crop consists of the crop sequence and cultural treatment of each rotation, the mean yield for the first half of the period, the mean yield for the last half of the period, the mean yield for the entire period, and the increase or decrease for each half of the period with the probable error of the difference, as compared with continuous cropping. The first rotation listed in each table is the plot in which that crop is grown continuously on the same land. Each rotation which follows this is compared with the continuously cropped plot. In instances where the rotation has been grown during less than the full 21-year period the comparison is made for only those years when both rotations were grown. When a crop is compared in two rotations and is found to yield higher in one than in the other, it is of value to know something of the uniformity of the differences. In order to determine the degree of dependability of the difference between two rotations, the probable error of the difference has been computed. This has been calculated from the formula

$$E \text{ (difference)} = 0.6745 \sqrt{\frac{\Sigma d^2}{N(N-1)}}$$

in which Σd^2 is calculated from an array of differences obtained by comparing the two rotations each year they have been under observation. In calculating Σd^2 by this method the difference between the two rotations in question for each year is determined. The mean difference is determined, then the deviations from this mean difference for each year are determined, squared, and summed. This represents Σd^2. N signifies the number of variates, or in this case the number of individual yields. A difference which is three times the probable error is usually considered significant.

The value of the probable error is that it indicates the variability of the differences between the two rotations compared. Thus, if in comparing two rotations one is found to yield more than the other, but upon examination it is found that this difference is not consistent, the dependability of the mean difference would be questioned. The probable error would be relatively high in such a case and would indicate that the difference was not significant.

In addition to the comparison of each rotation with continuous cropping, as presented in the table for each crop, other comparisons between particular rotations are made where possible. The effects of various cultural practices are pointed out for each crop. In certain instances the location or general fertility of a particular field or part of a field has appeared to influence the results, and where such a condition has existed and could be definitely recognized it has been noted in the text. Where insects or plant diseases have influenced the results, mention of them is also made, although obviously the measurement of such damage is not attempted.

OATS

The comparisons of the average annual yields of oats for grain are shown in Table 10. The mean yields for the full 21-year period are given for reference and comparison with the yields of the first half and the last half of the period. The increase or decrease of each rotation as compared with continuous cropping is shown. Three of these rotations were started since 1909 and are for shorter periods than the others. Rotation A5–C was added in 1910, and A4–F and A4–G were added in 1913.

TABLE 10.—*Mean annual acre yields of oats for grain (bushels) grown continuously on the same land as compared with the yields when grown in rotations at the San Antonio field station, 1909–1929*

Crop sequence and treatment	Rotation No.	Mean annual yield of oats for grain			Increase (+) or decrease (−) over continuous cropping during comparable years	
		1909–1920, 1922–1929	1909–1919	1920, 1922–1929	1909-1920, 1922–1929	1920, 1922–1929
Continuous:						
Oats (plowed October)	B5-8	19.9	13.7	27.3	----------	----------
2-year rotation:						
Oats (plowed June), fallow	A4-C	26.1	[1] 23.6	28.9	+8.5±2.1	+1.6±2.4
Oats (manured, subsoiled June), corn (plowed July).	A6-E	13.8	14.0	13.5	+ .3±2.7	−13.8±3
4-year rotation:						
Oats (plowed June), milo, field peas (plowed spring), sorghum (8-inch drills, plowed November), cotton (plowed fall).	A4-F	21.3	[2] 16.0	25.4	−1.1±1.7	−1.9±0.9
Oats (plowed June), milo, field peas, hay (plowed spring), sorghum (8-inch drills), cotton (plowed fall).	A4-G	21.5	[2] 17.4	24.6	+ .3±1.3	−2.7± .6
Oats (plowed June), cotton (plowed November), milo (plowed July), cotton (plowed fall).	A5-C	19.7	14.1	26.6	+ .4±1	− .7±1.3
Oats, cowpeas (plowed fall), cotton (plowed fall), milo (manured, plowed July), cotton (plowed November).	A5-D	12.5	10.6	14.8	−3.1±1.7	−12.5±2.8
Oats, cowpeas (subsoiled fall), cotton (plowed fall), milo (manured, subsoiled July), cotton (plowed November).	A5-E	12.0	10.6	13.7	−3.1±2.3	−13.6±3.2

[1] 10-year period, 1910–1919.

[2] 7-year period, 1913–1919.

It will be noted on examining Table 10 that the continuously cropped plot has the second highest yield for the last 10-year period and ranks fairly high for the 21-year period. The mean yield during the last 10 years was practically twice that of the first 11 years. With one exception, this tendency was noted to a lesser extent in all other rotations. The growing of crops continuously on the same land has long been recognized as a practice that eventually will prove detrimental to maintaining crop yields. As a rule, after a few years, yields decline, often quite rapidly. However, other factors may be involved whereby a restricted vegetative growth, which usually results from continuous cropping, may work to the advantage of the yield for many years, particularly when grain crops are involved. This appears to have occurred in the case of oats in these investigations.

Under the conditions in this region rust is a very important factor in oats production. Succulent, heavy growth maintains a condition of high humidity around the plants that appears to favor the rapid spread of the disease. When oats are grown continuously on the same land the plants are usually small and have relatively sparse foliage. When grown in rotations the plant growth is heavier and more succulent, and the disease is an important limiting factor. The disease rarely is serious on the continuously cropped plot.

In rotations the highest yield of oats has been obtained from biennial cropping in rotation A4–C. In this rotation one plot is planted to oats each year, while the alternate one is kept in clean fallow. Since an oats crop occupies the land only about 6 months, the actual fallow period is approximately 18 months. The purpose of this experiment was to determine whether sufficient moisture could be stored in the ground by fallowing to insure the production of profitable yields. Since by this method one-half of the land is idle each season, the annual yield per acre is in reality only one-half that shown. Consequently, although the mean yield of this rotation is relatively high, the practice can not be recommended.

The yield of oats for grain may be observed in only one other 2-year rotation. This is a rotation of oats and corn in which the land receives an application of barnyard manure after the corn crop and is subsoiled after the oat crop. It is located in field A6 at some distance from the other oats-for-grain plots. The soil of this field is deeper and less subject to drought injury than the land where the other oats plots are located. This feature, combined with the application of manure, favors abundant straw growth and resultant heavy rust infection. It is believed that these conditions contribute largely to the low grain yield of this rotation.

Oats were grown in five 4-year rotations. In the two rotations on field A4 the mean yield for the 21-year period was higher than from the continuously cropped plot, but during the last 10 years the yields were lower. The untreated rotation A5–C produced very nearly the same as the continuously cropped plot in all comparisons. Barnyard manure is applied to the cotton crop that precedes oats in the rotation A5–D, and in addition a green-manure crop is grown following oats. Rotation A5–E is similarly treated and in addition the land is subsoiled following each manure treatment. The yields of oats in these rotations are very low and substantiate the conclusion that under the conditions in the San Antonio region any treatment designed to stimulate plant growth depresses the grain yield of oats.

It appears that the rotations and cultural treatments practiced in these experiments which ordinarily favorably influence yields have produced either insignificant increases or actual losses in yield of grain as compared with the practice of continuous cropping.

The yields of oats harvested as hay are presented and compared in Table 11 in a manner similar to that used in Table 10. There has been no consistent change in the yields of hay during the last 10 years as compared with the first period under observation. The yield of hay under continuous cropping has increased. This is in agreement with the trend of yields in the continuously cropped oats-for-grain plot. Yields during the first period show that rotations yielded definitely more than did the continuously cropped plot, whereas during the last 10 years only two rotations have produced more. The differences during the latter period are small in all cases.

TABLE 11.—*Mean annual acre yields of oats (tons) for hay grown continuously on the same land as compared with yields when grown in rotations at the San Antonio field station, 1909–1929*

Crop sequence and treatment	Rotation No.	Mean annual yield of oats for hay			Increase (+) or decrease (−) over continuous cropping	
		1909–1929	1909–1919	1920–1929	1909–1919	1920–1929
Continuous:						
Oats (plowed May)	B5-7	1.61	1.49	1.75		
2-year rotations:						
Oats (plowed May), milo (plowed July).	A6-1A	1.86	1.97	1.73	+0.48±0.09	−0.02±0.13
Oats (plowed May), corn (plowed July).	A6-A	1.86	1.91	1.80	+ .42± .08	+ .05± .10
Oats (plowed November), corn (plowed July).	A6-B	1.89	[1] 2.11	1.72	+ .45± .07	− .03± .12
Oats (subsoiled May), corn (plowed July).	A6-C	1.74	1.73	1.76	+ .24± .09	+ .01± .12
3-year rotations:						
Oats (plowed June), cotton (plowed November), milo (plowed July).	A5-A	1.62	[1] 1.73	1.53	+ .07± .14	− .22± .13
Oats (plowed June), cotton manured (plowed November), milo (plowed July).	A5-B	1.48	[1] 1.63	1.36	− .03± .15	− .39± .08
Oats, field peas (plowed spring), cotton (plowed November), milo (plowed July).	B4-B	1.63	[1] 1.61	1.65	− .05± .16	− .10± .11

[1] 7-year period, 1913–1919.

There are four 2-year rotations in which the yield of oats for hay may be observed. The yields for these rotations for the 21-year period were higher than any others. This is partly due to their location on the more productive soil of field A6. In the last 10 years these 2-year rotations, with one exception, decreased in yield, whereas the yields under continuous cropping increased. For the full period under observation, oats alternated with corn has yielded exactly the same as when alternated with milo. Late fall plowing of oats, as in rotation A6–B, has produced almost the same yields as May plowing. Subsoiling, as practiced on rotation A6–C, appears to have depressed the yield during the first period. In the 3-year rotations the yields are very nearly the same as under continuous cropping. In the untreated 3-year rotation A5–A and the manured rotation A5–B, the yields decreased during the last 10 years, whereas in the rotation which grows a green-manure crop, B4–B, the yield remained very nearly constant. The rotation which received manure had a lower yield than the adjoining one not manured. Green manure apparently had little effect unless it tended to hold the yield constant.

The yields of oats under the prevailing conditions at the San Antonio field station were so low that it is evident the crop can not be recommended, except where it is planted primarily to furnish winter pasturage and is permitted to make grain only when early spring prospects are favorable. Rust damage is usually much less serious in oat fields that have been pastured during the winter than in those in which the plants have made unrestricted growth.

CORN

The comparisons of the annual yields of corn, together with the crop sequences and cultural treatments, are shown in Table 12. These comparisons also are divided into two periods, and yields are given separately for the first 11 years and the last 10 years. All the rotations in which corn was grown are 2 years in length. There are 19 such rotations and two plots on which corn was grown continuously.

TABLE 12.—*Mean annual acre yields (bushels) of corn grown continuously on the same land as compared with corn grown in rotations, showing the effects of cultural treatments, at the San Antonio field station, 1909–1929*

Crop sequence and treatment	Rotation No.	Mean annual yields of corn			Increase (+) or decrease (−) over continuous cropping	
		1909–1929	1909–1919	1920–1929	1909–1919	1920–1929
Corn (continuous, plowed July)	B5-1	24.2	21.1	27.6		
Corn (continuous, manured, plowed July).	B5-2	24.9	24.4	25.5	+3.3±1.0	−2.1±0.9
Corn (plowed July), fallow	A4-B	23.7	[1] 20.5	27.0	−2.6±1.7	−.6±1.7
Corn (plowed July), cotton (plowed November).	A4-D	24.2	[2] 20.2	27.8	−5.1±1.6	+.2±1.5
Corn (plowed July), oats (plowed May)	A6-A	32.9	31.5	34.4	+10.4± .4	+6.8±1.5
Corn (plowed July), oats (plowed November).	A6-B	26.9	23.5	30.7	+2.4±1.3	+3.1±1.2
Corn (plowed July), oats (subsoiled May).	A6-C	30.9	27.7	34.5	+6.6±1.3	+6.9±1.3
Corn (plowed July), milo (plowed fall)	A6-D	27.9	24.6	31.5	+3.5±1	+3.9±1.3
Corn (plowed July), oats (manured, subsoiled June).	A5-E	30.0	27.3	33.0	+6.2±1.2	+5.4±1.3
Corn (plowed July), Sudan grass (manured, plowed November).	A6-F	29.3	24.3	34.8	+3.2±1.3	+7.2±1.7
Corn (plowed July), sorghum (4.1-foot rows, plowed November).	B5-C	23.3	19.6	27.3	−1.5± .9	−.3±1.4
Corn (plowed July), sorghum (8-inch drills, plowed November).	B5-D	23.3	20.1	26.8	−1.0±1.4	−.8±1.3
Corn (plowed July), cotton (plowed November).	B6-A	30.2	26.5	34.3	+5.4±2.3	+6.7±2
Corn (subsoiled July), cotton (subsoiled November).	B6-B	30.3	26.3	34.7	+5.2±1.7	+7.1±1
Corn (manured, plowed July), cotton (plowed November).	B6-C	30.1	26.9	33.6	+5.8±2.3	+6.0±1.5
Corn (manured), field peas (plowed spring), cotton (plowed November).	B6-D	29.8	26.5	33.3	+5.4±2.4	+5.7±1.2
Corn (manured), field peas (plowed spring), cotton (subsoiled November).	B6-E	30.4	27.1	34.0	+6.0±2.1	+6.4±1.1
Corn (disked July), cotton (plowed November).	B6-F	29.8	27.0	32.9	+5.9±1.9	+5.3±1.1
Corn (plowed February), cotton (plowed February).	B6-G	28.9	25.4	32.8	+4.3±1.7	+5.2±1.2
Corn (subsoiled February), cotton (subsoiled February).	B6-H	28.4	24.6	32.6	+3.5±1.8	+5.0±1.8
Corn, rye (plowed February), cotton (plowed November).	B6-I	30.1	26.4	34.1	+5.3±2	+6.5±1.5

[1] 10-year period, 1910–1919.

[2] 9-year period, 1911–1919.

One of the outstanding features of the results of this experiment with corn is the uniformity of yields regardless of treatment. While there are significant differences in some cases, still the range from 23.3 bushels to 32.9 bushels is rather small. Another feature of the data is the relatively high yield of the two continuously cropped plots, especially when they are compared with rotations near them.

From observations it appears that the principal limiting factor in corn production under the conditions of the experiment is rainfall. This would explain the lack of response to a rotational or cultural treatment. In order to ascertain more accurately the influence of rainfall upon the yield of corn, a comparison has been made of the rainfall of various periods as related to the yields of corn. It was found that the rainfall of the entire season influenced the yield more than did the rainfall of any one part of the season. The relation of corn yields and rainfall from November to July is shown in Figure 2. It is clear that the rainfall during this period influenced to a great extent the yield of corn. The correlation is found to be +0.9, which is high. There are some exceptions in the graph, probably due to the character and distribution of the rainfall. Rainfall of torrential nature or the occurrence of a large percentage of the rainfall during one particular month would, of course, be of less value to the crop than if evenly distributed, and the correlation would be lower in such cases. A good example of distribution is found in studying the years 1919 and 1920. In 1919 both the yields of corn and the total rainfall were high. In 1920 the yield of corn was slightly higher than in 1919, but the rainfall was much lower. Precipitation for the previous December and January was above the average, followed by very low rainfall in February, March, and April. Apparently there was sufficient moisture to keep the crop growing during the early months. This was followed by better than average precipitation in May and almost twice the normal for June, with about the average for July. The crop was supplied with abundant moisture at the critical time, and very good yields resulted. A study has also been made of the correlation between the rainfall for the three months May, June, and July. It appears that the rainfall of this period is an important factor in influencing yields, and there is some correlation, but the rainfall for the longer period, November to July, correlates more closely with the yields.

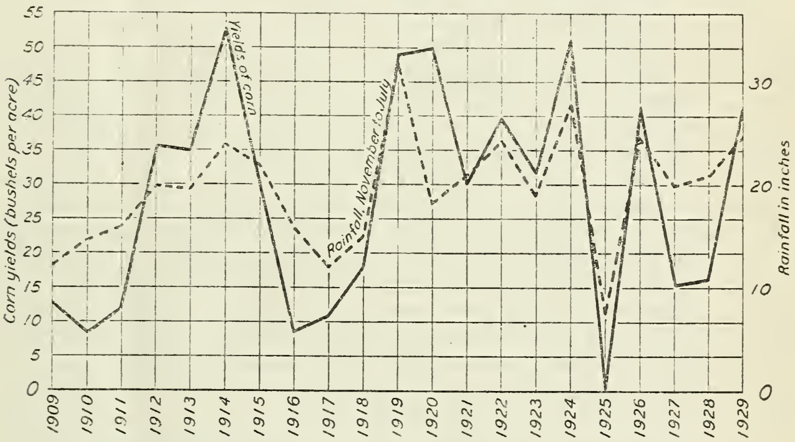

FIGURE 2.—Comparison of the annual yields of corn with the seasonal rainfall

All the yields of corn during the last 10-year period are higher than those for the first 11-year period. The increases appear to be very nearly the same in all rotations and to be due more to favorable seasonal conditions than to treatments given the rotations. The highest yield is from a 2-year rotation of oats and corn, namely, A6–A. Corn is planted following plowing of oats in May. This rotation has produced 8.7 bushels more on the average than corn grown continuously on the same land. The increase when compared with continuous cropping is not as great for the last 10-year period as for the first 11 years.

Corn grown continuously on plot B5–1 increased in yield during the last period of the experiment. The adjoining plot, B5–2, which received an application of barnyard manure, increased by a much smaller amount. The yields of B5–2 for the first 11 years were higher than for B5–1, untreated. Two factors, it is believed, are responsible for the lack of favorable response to applications of manure: (1) Weeds are always more plentiful on the manured plots, and their excessive growth during periods of wet weather often retards the normal crop development before they can be removed; (2) the corn plant itself makes use of the increased fertility during early-season periods of plentiful soil moisture to produce a large, succulent growth that makes heavy demands on the soil moisture and rapidly depletes it when droughts occur during the later and more critical stages of development.

Yields of corn in the corn-fallow rotation A4–B have been lower than under continuous cropping or in the 2-year rotation A4–D, which is bordered. The difference is rather insignificant, but it is plain that under the conditions of the experiment yields have not been increased by fallowing. The bordering of land has apparently had no beneficial effect, as the yield of rotation A4–D, which is bordered, is the same as under continuous cropping. The yields of corn following forage sorghum, in field B5, are the lowest of the experiment, apparently due to the deleterious aftereffects of the sorghum crop.

In the 2-year rotations on fields A6 and B6 the yields were higher than in the other fields. It is believed this was primarily due to the greater depth and natural fertility of the soil in these fields. Early plowing following an oat crop appears to result in increased yields, when rotation A6–A is compared with A6–B, in which fall plowing was practiced. Subsoiling in May, as in rotation A6–C, appears to have slightly reduced the yield, although the difference is small. The same tendency is noted in A6–E, where manure was also applied. It will be observed that rotation A6–D, in which corn was alternated with milo plowed in the fall, yielded nearly the same as A6–B which was fall plowed and in which oats were the alternate crop. It thus appears that the time of plowing is more important than the previous crop. Corn following Sudan grass has produced yields equal to those following the other crops.

All the yields from the different rotations in field B6 were nearly the same and indicated no significant advantage resulting from subsoiling or from the use of barnyard manure or green manures, or from combinations of these. While the differences between the yields of these rotations and the continuously cropped plot, B5–1, were only slightly greater during the last 10 years than during the first 11 years, these differences were more consistent and accordingly more significant. In general it appears that corn yields may be increased by rotation with any of the crops except hay sorghums and that none of the special cultural practices in this experiment influenced the yields appreciably, although summer or early fall plowing shows some advantage compared with winter or spring plowing. The chief limiting factor in corn production under the conditions prevailing at the San Antonio Field Station appears to have been rainfall distribution.

MILO

The comparison of the average annual yields of milo is shown in Table 13. Milo has been grown in the rotations only since 1912 and 1913, so the period under observation is less than for most of the other crops. As has been mentioned, the yields of milo were lower for the last 10 years than for the first 8 years. Two complete crop failures have occurred since 1920.

TABLE 13.—*Mean annual acre yields (bushels) of Dwarf Yellow milo grown continuously on the same land as compared with yields when grown in rotations, showing the effects of manuring and subsoiling at the San Antonio field station, 1909–1929*

Crop sequence and treatment	Rotation No.	Mean annual yield of milo			Increase (+) or decrease (−) over continuous cropping during comparable years	
		1912–1929	1912–1919	1920–1929	1912–1919	1920–1929
Continuous:						
Milo (plowed July)	A6-1	16.8	19.7	14.5		
Milo (manured, plowed July)	A6-2	24.3	33.2	17.2	+13.5±2.6	+2.7±2.2
2-year rotations:						
Milo (plowed July), oats for hay (plowed May).	A6-1A	20.5	25.1	16.8	+5.4±1.5	+2.3±1.0
Milo (plowed fall), corn (plowed July).	A6-D	20.8	26.0	16.7	+6.3±2.1	+2.2±1
Milo (plowed July), cotton (plowed November).	B5-E	20.8	23.1	18.9	+3.4±2.3	+4.4±1.4
3-year rotations:						
Milo (plowed July), oats for hay (plowed June), cotton (plowed November).	A5-A	24.8	[1] 27.1	23.2	+9.2±3.5	+8.7±1.7
Milo (plowed July), oats for hay (plowed June), cotton (manured, plowed November).	A5-B	27.3	[1] 32.1	23.8	+14.2±4.4	+9.3±2.3
Milo (plowed July), Sudan grass (plowed November), cotton (plowed November).	B4-A	22.1	[1] 22.7	21.6	+4.8±3.6	+7.1±1.9
Milo (plowed July), oats, field peas (plowed spring), cotton (plowed November).	B4-B	24.9	[1] 28.2	22.5	+10.3±3.7	+8.0±1.8
4-year rotations:						
Milo, field peas (plowed spring), sorghum (8-inch drills, plowed November), cotton (plowed fall), oats (plowed June).	A4-F	24.8	[1] 27.9	22.7	+10.0±3.8	+8.2±2.0
Milo, field peas (hay, plowed spring), sorghum (8-inch drills, (plowed November), cotton (plowed fall), oats (plowed June).	A4-G	25.5	[1] 29.0	23.1	+11.1±2.8	+8.6±1.3
Milo (plowed July), cotton (plowed fall), oats (plowed June), cotton (plowed November).	A5-C	27.1	[1] 30.1	25.1	+12.2±3.7	+10.6±2.0
Milo (manured, plowed July), cotton (plowed fall), oats, cowpeas (plowed fall), cotton (plowed November).	A5-D	29.2	[1] 33.7	26.0	+15.8±3.9	+11.5±2.1
Milo (manured, subsoiled July), cotton (plowed fall), oats, cowpeas (subsoiled fall), cotton (plowed November).	A5-E	26.8	[1] 29.9	24.6	+12.0±2.8	+10.1±2.8

[1] 7-year period, 1913–1919.

Grain-sorghum yields in the San Antonio region are materially influenced by the sorghum midge. In some seasons very little damage occurs, while in others the damage is severe. In 1920 the complete failure of milo was caused by this insect. It has been found that early planting serves to bring the crop into flower at a time when the midges are least numerous and thereby reduces the damage to a minimum. In so far as possible the practice of early planting has been followed (*3*, *8*).

Damage by birds, especially English sparrows, is another disturbing element in the growing of grain sorghum under experimental conditions. The damage is not evenly distributed over the fields, and some plots may be practically destroyed while others are damaged very little. Consequently, when the various milo plots in the different rotations are compared, the yields recorded often do not reflect accurately yield trends. Also, such conditions place milo at a disadvantage when compared with corn. Although the bird hazard must be considered whenever grain sorghums are grown, it is believed its importance is appreciably less when larger acreages of the crop are grown.

The results given in Table 13 clearly indicate that continuous cropping of grain sorghum is not a desirable practice, as the yields were about 4 bushels below those of any other rotation. Applications of manure in plot A6–2, which is continuously cropped, have definitely increased yields. The increase in yield resulting from applications of manure was less consistent in recent years, the mean of A6–2 being only 2.7 bushels above the untreated plot for the last 10 years. This difference is within the limits of experimental error. Applications of manure under the conditions existing always cause abundant weed growth. This necessitates extra work in caring for the crop.

In the 2-year rotations that include milo the yields for the 18-year period were very uniform. The yields were higher than in the untreated continuously cropped plot, but in some cases the increases were not significant. The probable error of the difference between yields was higher for the first period than for the last, indicating that the yields were quite variable during the first eight years. Oats, corn, and cotton appear to be equally desirable to rotate with milo in a 2-year rotation. However, the reduction in yield of the last period as compared with the first is less where cotton is the alternate crop.

In 3-year rotations all the yields of milo were significantly higher than from continuous cropping and were also higher than from the 2-year rotations. The yield of rotation A5–B, which received manure, was 2.5 bushels higher than that of rotation A5–A. In this instance, as under continuous cropping, the greatest increases from applications of manure were obtained during the first seven years. During the last 10 years the two rotations have returned practically the same yields. In rotation B4–B a green-manure crop apparently had no effect as compared with rotation A5–A. The field peas are grown before the cotton crop rather than previous to milo. The differences during the last 10-year period were all small, indicating that such a practice is not justified in the San Antonio region as far as milo is concerned.

The mean yield of the 4-year rotations was higher than that of the 3-year rotations. Rotation A5–D in this series produced the highest yield throughout the period. Rotation A5–E, adjoining, which was subsoiled, had a lower yield. The rotations on field A4 had a somewhat lower yield than those on field A5. It is quite possible that this small difference may have been due to soil variation. The presence of 2 sorghum crops (1 grain and 1 forage) in the 4-year rotations on field A4 may also have been a factor of importance.

It appears from the results of this experiment that milo is most productive in 3 or 4 year rotations. Two-year rotations appear to be superior to continuous cropping but inferior to the longer rotations. A slight response to applications of barnyard manure is noted, while no significant differences seem to have been effected by subsoiling or by including a green-manure crop.

SORGHUM

The comparisons of the average annual yields of forage sorghum are presented in Table 14. Sorghum for forage was grown in 4.1-foot rows in five rotations, all but one of which were started in 1909. In seven rotations the sorghum was grown in 8-inch drills. Three of these were started in 1909, 3 in 1913, and 1 in 1914.

TABLE 14.—*Mean annual acre yields (tons) of forage sorghum grown continuously on the same land as compared with yields when grown in rotations at the San Antonio field station, 1909–1929*

Crop sequence and treatment	Rotation No.	Mean annual yields of sorghum			Increase over continuous cropping during comparable years	
		1909–1929	1909–1919	1919–1929	1909–1919	1919–1929
Continuous:						
Sorghum (plowed November)	B5-5	3.82	4.25	3.35		
Do	A6-4	3.26	3.69	2.78		
Mean		3.54	3.97	3.07		
Sorghum (plowed November), fallow.	A4-E	4.20	[1] 4.93	3.54	+0.58±0.33	+0.47±0.13
Sorghum (plowed November), cotton (plowed November).	B5-A	4.16	4.42	3.88	+.45± .12	+.81± .16
Sorghum (plowed November), corn (plowed July).	B5-C	4.47	4.98	3.92	+1.01± .14	+.85± .15
Sorghum in 8-inch drills:						
Sorghum (continuous, plowed November).	B5-6	3.35	3.62	3.06		
Sorghum (continuous, manured, plowed November).	B4-12	5.29	[2] 5.59	5.12	+1.30± .54	+2.06± .51
Sorghum (continuous, manured alternate years, plowed November).	B4-13	4.92	[3] 5.54	4.48	+1.29± .28	+1.42± .41
Sorghum (plowed November), cotton (plowed fall), oats (plowed June), milo, field peas (plowed spring).	A4-F	4.59	[3] 5.87	3.70	+1.62± .33	+.64± .30
Sorghum (plowed November), cotton (plowed fall), oats (plowed June), milo, field peas for hay (plowed spring).	A4-G	4.43	[3] 5.47	3.71	+1.22± .39	+.65± .35
Sorghum (plowed November), cotton (plowed November).	B5-B	5.00	4.76	5.25	+1.14± .25	+2.19± .53
Sorghum (plowed November), corn (plowed July).	B5-D	5.55	5.81	5.25	+2.19± .32	+2.19± .52

[1] 9-year period, 1911–1919.
[2] 6-year period, 1914–1919.
[3] 7-year period, 1913–1919.

Two plots planted in 4.1-foot rows were continuously cropped. The mean of these two plots was used in making comparisons with the three other plots, all of which were in 2-year rotations. In B5–C the sorghum was alternated with corn, and this rotation had the highest yield. In B5–A, where cotton was the alternate crop, the yield was lower than where corn was grown, although the difference was rather small. Cotton grows much later in the season than corn, and it is quite possible that the continued removal of moisture until late in the fall was responsible for this difference. In rotation A4–E, where the land was fallowed between sorghum crops, the yield was intermediate between the rotations previously mentioned. As was the case with oats and corn, fallow failed to influence materially the yield of the following crop. It is of interest to note, in connection with statements previously made regarding differences of yield due to plot variations, that the differences between the two continuously cropped and similarly treated plots, A6–4 and B5–5, are nearly as great as between the higher of these two and the best of those grown in rotation with other crops.

Plot B5–6 is used for comparison of the rotations in which sorghum is planted in 8-inch drills. The yield of this plot is much lower than that of any of the rotations. It appears that sorghum is much more responsive to rotational and cultural treatment when grown in drills than when grown in rows. Two plots on field B4 were continuously cropped to sorghum, one receiving an application of manure every year while the other received an application of manure every alternate year. The yields of both these plots were very much higher than the yield of the continuously cropped plot which was untreated. In view of the high probable errors, the difference between B4–12 and B4–13 is probably not significant. Although applications of manure increased the yield of sorghum in these plots, the quality of hay was materially reduced. The manure used in these experiments was, in many instances, procured from outside sources and was badly infested with weed seeds. In some instances the crops produced on these plots were almost 100 per cent weeds. Such crops are not included in the yields, but other crops which have a smaller percentage of weeds must be included. These contribute to the high yield but reduce the quality of hay.

Drilled sorghum in rotations yielded more than under continuous cropping. Rotation B5–B, in which cotton was the alternate crop, produced 5 tons per acre, while in a near-by rotation in which corn was the alternate crop the yield was 5.55 tons per acre. This relation of higher yield following corn is similar to that where sorghum was grown in rows and may be due to the difference in time of removal of the previous corn and cotton crops. In the 4-year rotations on field A4 the yield was lower than in the 2-year rotations. There was little difference between these two rotations, and the yields for the full period were very nearly the same. In both these 4-year rotations sorghum followed field peas grown as a green-manure crop following milo. In this sequence the land was occupied through most of the previous year and this, combined with the effect of late spring plowing, probably accounts for the lower yield of these rotations.

In general, sorghum planted in drills or broadcast has been found to yield more and to produce a better quality of hay than when grown in rows. Applications of manure to sorghum increased the yield, but the quality of hay was reduced because of weed growth and the increase did not justify the added expense. Corn is apparently a better crop than cotton to alternate with sorghum in a 2-year rotation, considering the yield of sorghum. Four-year rotations in which sorghum follows milo and field peas for green manure did not yield as well as drilled sorghum in 2-year rotations. Fallowing the land for one season between crops of sorghum did not produce better yields than simple 2-year rotations.

SUDAN GRASS

Sudan grass was grown in two rotations in these experiments. In one instance it was grown in a 2-year rotation following corn, while in the other it was grown in a 3-year rotation following milo. The soil in rotation A6–F is much deeper and more fertile than where B4–A is located. Therefore no comparison is made between the two rotations. There was no continuously cropped plot of Sudan grass with which to compare the yields in rotations, but the data for the two rotations are given in Table 15.

TABLE 15.—*Mean annual acre yields (tons) of Sudan grass at the San Antonio field station, 1913–1929*

Rotation	Crop sequence and treatment	Mean annual yields of Sudan grass		
		1913–1929	1913–1919	1919–1929
A6–F	Sudan grass (manured, plowed November), corn (plowed July)	[1] 5.52	[2] 6.22	5.09
B4–A	Sudan grass (plowed November), cotton (plowed November), milo (plowed July)	4.34	5.06	3.84

[1] 16-year period, 1914–1929.

[2] 6-year period, 1914–1919.

Manure was applied in rotation A6–F and, as in the case of sorghums, seriously increased the weed growth. The Sudan grass proved to be better able to compete with the weeds than the sorghum, however, so that the weeds were less important. The mean yield of Sudan grass was higher than that of sorghum and the quality of hay was usually superior.

COTTON

Cotton production in the San Antonio area is influenced materially by the cotton boll weevil (*Anthonomus grandis* Boh.) and by the cotton root-rot disease (*Phymatotrichum omnivorum* (Shear) Duggar). Although boll weevils are destructive nearly every year, the extent of their injury varies from a small percentage of the crop to complete destruction. The 1929 crop was entirely destroyed by this insect. The damage done by boll weevils was fairly uniform on all fields so far as could be observed, so that comparisons between rotations were not distorted from this cause. At times the bollworm (*Heliothis obsoleta* Fab.), the leaf worm (*Alabama argillacea* Huebn.), and the flea hopper (*Psallus seriatus* Reut.) damage the crop to some extent. The damage resulting from cotton root rot is not evenly distributed, and its effect on yields is more difficult to determine. A subsequent chapter is devoted to the effect of this disease upon the yields of cotton.

The comparisons of the yields of cotton are shown in Table 16. There were two untreated plots on which cotton was grown continuously. The mean of these two plots was used in making comparisons. The yields of cotton under continuous cropping were considerably lower than in the best 2-year rotations but were higher than in some. The mean yield of plots A6–3 and B5–3 was 329 pounds of seed cotton per acre. Applications of manure on plot B5–4 apparently had no significant effect upon the yield. Plowing under a green-manure crop on plot A4–19 apparently depressed the yield somewhat, although the decrease was small.

TABLE 16.—*Mean annual acre yields (pounds) of seed cotton grown continuously on the same land as compared with yields when grown in rotations, showing the effects of different cultural treatments at the San Antonio field station, 1909–1929*

Crop sequence and treatment	Rotation No.	Mean annual yields of cotton			Increase (+) or decrease (−) over continuous cropping during comparable years	
		1909–1929	1909–1919	1920–1929	1909–1919	1920–1929
Continuous:						
Cotton (plowed November)	A6-3	350	483	205		
Do	B5-3	308	423	182		
Mean		329	453	194		
Cotton (manured, plowed November)	B5-4	341	461	209	+8±30	+15±24
Cotton, field peas (plowed spring)	A4-19	251	[1] 353	180	−44±25	−14±12
2-year rotations:						
Cotton (plowed November), fallow	A4-A	215	[2] 336	94	−78±37	−100±23
Cotton (plowed November), corn (plowed July).	A4-D	292	[3] 423	174	−2±40	−20±22
Cotton (plowed), sorghum (4.1 foot rows, plowed November).	B5-A	362	430	287	−23±22	+93±29
Cotton (plowed November), sorghum (8-inch drills, plowed November).	B5-B	334	389	273	−64±20	+79±26
Cotton (plowed November), milo (plowed July).	B5-E	336	456	204	+3±35	+10±20
Cotton (plowed), corn (plowed July)	B6-A	420	546	282	+93±17	+88±23
Cotton (subsoiled), corn (subsoiled November).	B6-B	392	530	241	+77±20	+47±19
Cotton (plowed), corn (manure, plowed July).	B6-C	521	635	396	+182±49	+202±38
Cotton (plowed), corn, field peas (manure, plowed spring).	B6-D	534	656	401	−203±43	+207±41
Cotton (subsoiled November), corn (manure), field peas (plowed spring).	B6-E	507	647	354	+194±40	+160±38
Cotton (plowed November), corn (disked July).	B6-F	442	591	277	+138±23	+83±22
Cotton (plowed February), corn (plowed February).	B6-G	378	490	254	+37±17	+60±20
Cotton (subsoiled February), corn (subsoiled February).	B6-H	361	433	282	−20±15	+88±23
Cotton (plowed November), corn, rye (plowed February).	B6-I	321	395	239	−58±36	+45±19
3-year rotations:						
Cotton (plowed November), milo (plowed July), oats (plowed June).	A5-A	392	500	274	+47±38	+80±23
Cotton (manure, plowed November), milo (plowed July), oats (plowed June).	A5-B	401	496	297	+43±43	+103±20
Cotton (plowed November), milo (plowed July), Sudan grass (plowed November).	B4-A	305	[1] 431	217	+34±23	+23±22
Cotton (plowed November), milo (plowed July), oats (fallow), peas (plowed spring).	B4-B	366	[1] 493	277	+96±42	+83±29
4-year rotations:						
Cotton (plowed fall), oats (plowed June), milo, field peas (plowed spring), sorghum (plowed November).	A4-F	266	[1] 374	191	−23±32	−3±17
Cotton (plowed fall), oats (plowed June), milo, field peas, hay (plowed spring), sorghum (plowed November).	A4-G	281	[1] 382	210	−15±32	+16±18
4-year rotations, cotton occurring twice:						
Cotton (plowed November), milo (plowed July), cotton (plowed fall), oats (plowed June).	A5-C1	360	460	250	+7±50	+56±19
Cotton (plowed fall), oats (plowed June), cotton (plowed fall), milo (plowed July).	A5-C2	354	435	266	−18±43	+72±22
Cotton (plowed November), milo (manure, plowed July), cotton (plowed fall), oats, cowpeas (plowed fall).	A5-D1	377	466	280	+13±42	+86±21
Cotton (plowed fall), oats, cowpeas (plowed fall), cotton (plowed November), milo (manure, plowed July).	A5-D2	385	475	286	+22±39	+92±28

[1] 7-year period.

[2] 10-year period.

[3] 9-year period.

TABLE 16.—*Mean annual acre yields (pounds) of seed cotton grown continuously on the same land as compared with yields when grown in rotations, showing the effects of different cultural treatments at the San Antonio field station, 1909–1929*—Con.

Crop sequence and treatment	Rotation No.	Mean annual yields of cotton			Increase (+) or decrease (−) over continuous cropping during comparable years	
		1909–1929	1909–1919	1920–1929	1909–1919	1920–1929
4-year rotations, cotton occuring twice—Con.						
Cotton (plowed November), milo (manure, subsoiled July), cotton (plowed fall), oats, cowpeas (subsoiled fall).	A5–E1	385	480	280	+27±30	+86±27
Cotton (plowed fall), oats, cowpeas (subsoiled fall), cotton (plowed November), milo (manure, subsoiled July).	A5-E2	399	501	286	+48±43	+92±35

In the 2-year rotations the yields were quite variable, ranging from 215 pounds of seed cotton per acre in A4–A to 534 pounds in rotation B6–D. One factor in this range was the difference in location and the consequent variation in soil. In making comparisons, location must be taken into consideration. In the cotton-fallow rotation A4–A the yield was the lowest in the experiment, even lower than in any continuously cropped plot. The loss from root rot was high in this rotation, but no higher than in some of the continuously cropped plots, so the low yield can not be attributed wholly to the disease. It is not understood why the yields of this rotation were so low. All crops have failed to respond to the practice of fallowing, but there was no reason to expect that it would cause a depression in yield. Bordering the land to prevent run-off of rainfall in rotation A4–D also failed to increase the yield of cotton. The yields were just about equal to continuous cropping. Cotton was alternated with corn in this rotation. As has been noted, the corn yields were also low in this rotation. In field B5 the cotton was alternated with sorghum crops, in two cases with forage sorghum and in one with grain sorghum. The yields of these three rotations were very uniform and were about equal to those of the untreated continuously cropped plots. During the last 10 years the yields of B5–A and B5–B were higher than in the continuously cropped plots, whereas during the first 11 years the yields were lower. It appears from this that these two rotations were of value in building up the yields of cotton. Milo in rotation B5–E failed to bring about an increase during the last 10-year period.

In field B6 the highest yields were produced in rotations B6–C, B6–D, and B6–E. All these rotations received applications of barnyard manure, while B6–D and B6–E included a green-manure crop and B6–E was subsoiled in addition. The difference in yields between any two of these three rotations was small. Therefore it appears that manuring is the important factor in increasing the yields, as applications of green manure and the practice of subsoiling failed to increase the yields materially above that in rotation B6–C, where manure alone was applied. The reaction in these rotations was very nearly the same in all the periods compared. The increase of yield of cotton in the simple corn-cotton rotation B6–A over continuous cropping was approximately 100 pounds per acre. Subsoiling appears to have reduced the yield somewhat in all cases in this field. The reduction was rather small, however. In rotation B6–F, cotton was planted on disked cornland, but the mean yield for the entire period from this rotation is slightly in excess of that harvested from B6–A, with which it is identical as to crops and treatment except that the cornland is plowed in July in the case of B6–A. It is of interest to note, however, that the increase of rotation B6–A over continuous cropping was maintained throughout the period, whereas in the rotation B6–F the comparative yields fell off, and the increase over continuous cropping during the last 10 years was rather small. Late preparation of land—February plowing in rotation B6–G and B6–H—gave lower yields than early plowing in rotation B6–A. These yields were below even those of cotton on disked cornland. Subsoiling at this date apparently had little effect upon yield.

Rye as a green-manure crop in rotation B6–I appears to have depressed the yield of cotton. This is probably due to the fact that rye utilizes the available moisture and plant food during the winter months, and spring plowing of the sod leaves the ground in a dry, cloddy condition unless the spring rains are in excess of normal. Retarded and spotted germination with poor stands were common in this rotation. The depressing effect is less apparent in the last 10-year period than during the first 11 years, however. The difference in yields between this rotation and cotton grown continuously on the same land changed from a decrease of 58 pounds to an increase of 45 pounds. The probable errors, however, were high.

The yields of cotton in 3-year rotations did not show as great increases over continuous cropping as ordinarily might be expected. In two instances the increases were significant. In rotations A5–A and A5–B, in relation to continuous cropping, the yields improved during the last 10 years and show significant increases for this period. The manured rotation A5–B improved more than the untreated one. In the rotations B4–A and B4–B the increases over continuous cropping were quite small for each period covered. The yields were materially less in rotation B4–B than in A5–A, again indicating a depressing effect from plowing under a green-manure crop in the spring.

Cotton was grown in two 4-year rotations, each of which included a green-manure crop. In rotation A4–G the field peas were harvested for hay, while in A4–F they were plowed under. The cotton yields in these rotations were quite low. Plot A4–19 was continuously cropped to cotton, with a green-manure crop of field peas grown during the winter. The yield of this plot was nearly equal to that from the 4-year rotations. The fact that cotton followed two years of sorghum, one of grain, and the other of forage type, possibly explains these low yields. In each of the 4-year rotations on field A5 cotton occurred twice, once following oats and the second time following milo. The cotton yields from these three rotations were slightly lower than those from the 3-year rotations A5–A and A5–B. In presenting the data for these three rotations, the yields of the plot in which cotton follows oats are carried through each period and given separately from those of the plot in which cotton follows milo in the rotation. The yields are very nearly the same, indicating that in this case the previous crop has had little effect upon the yield. Although the yields from rotations A5–D and A5–E are slightly higher than those from the untreated rotation A5–C, the differences are small. Apparently subsoiling has not influenced the yields in rotation A5–E as compared with those in A5–D.

In general it appears that rotation of crops as compared with continuous cropping increased the yield of cotton, but the increase was small in many instances. The yields in 3-year rotations have not been consistently better than in 2-year rotations, while the 4-year rotations, in which cotton follows two sorghum crops, have yielded no better than continuous cropping. Barnyard manure failed to affect the yield of cotton under continuous cropping but increased the yield in all rotations, particularly those having a 2-year cycle. Green-manure crops depressed the yields of cotton in most instances, although in some rotations no difference in yield was observed. Forage sorghums depressed the yields, while milo apparently did not. The difference in after effect of the two types of sorghum is probably due to the fact that the former occupies the land until frost while the latter is harvested and the ground plowed in late summer. Following corn and cotton, late winter plowing was less desirable than summer and fall plowing.

COMPARATIVE MERITS OF DIFFERENT CROPS AND ROTATIONS

The effects of the various rotational and cultural practices on each separate crop have been discussed in the preceding pages. The following discussion deals with the merits of the various rotations and cultural treatments from the standpoint of all crops.

Growing a crop continuously on the same land is usually considered a poor farming practice. In these experiments this practice has been tested for each crop except Sudan grass. The effects of applications of barnyard manure on continuously cropped corn, cotton, sorgo, and milo have been tested, and field peas for green manure have been grown as a winter crop in connection with continuous cotton. While the results indicate that in general continuous cropping is not desirable, the yields in some instances have been very nearly as high as in rotations. Oats have produced as good and in most instances better yields under continuous cropping than when the crop is grown in rotations. This has been attributed to the influence of stem rust and leaf rust. Rainfall distribution has been the chief limiting factor in the production of corn, and the yields have been very nearly as high under continuous cropping as in rotations. Milo and forage sorghum under continuous cropping have been satisfactory, but they have responded readily to applications of barnyard manure. Cotton under continuous cropping has produced rather low yields and has not responded appreciably to applications of barnyard manure. A winter green-manure crop has had a slightly depressing effect.

The practice of alternate cropping and fallowing was carried on with cotton, corn, oats, and forage sorghum. The yields of corn and cotton were below those of continuously cropped plots, while the yields of forage sorghum were about the same. Oat yields were higher than in rotations, but the increase was not sufficient to justify the practice. Fallowing the land a full season between crops has not proved of practical value under the conditions existing at San Antonio.

The practice of bordering land to prevent run-off of rainfall has been tested for corn, cotton, and forage sorghum. The corn and cotton were grown in a 2-year rotation, and the yields have been very low for both crops. The forage-sorghum crop was grown in a rotation of alternate sorghum and fallow. The combined effect of the fallow and bordering failed to increase the sorghum yields above those secured when sorghum was included in a 2-year rotation with another crop. It appears that bordering on shallow soil, such as exists where these investigations were conducted, has not materially influenced crop yields.

Most of the crops grown in 2-year rotations were located in field 6. Five were located in field B5, of which 4 consisted of forage sorghum alternated with corn or cotton, and 1 of corn and milo. In field A6 the rotations consisted of corn alternated with milo, oats, or Sudan grass. In field B6 corn was alternated with cotton, and a variety of cultural treatments were tested. The desirability of a rotation usually depends upon the individual needs or desires of the farmer. Therefore it is impossible to pick out one rotation as being better than another except when the comparison is made between two rotations that include the same crops. In field A6 the most desirable rotation of corn and oats appeared to be A6–A. This consisted of oats plowed in May, followed by corn plowed in July. Later plowing of the oats stubble, as practiced in A6–B, appears to be distinctly less desirable from the standpoint of corn production, while there is little difference in the yield of oats. Subsoiling in rotation A6–C did not produce as good yields. In rotation A6–D milo was alternated with corn instead of oats. The yields of corn were not as good as in the rotations with oats, and the yields of milo were low. In rotation A6–E oats for grain were included, but the yields of grain were very low because of rust damage induced by rank plant growth following applications of barnyard manure. The last rotation in this series had a crop of Sudan grass alternated with the corn. This appears to be a satisfactory rotation where a forage crop is desired.

In field B6, where corn was alternated with cotton, the differences in corn yields were small. Cotton yields, however, vary according to the treatment, and for this reason the desirability of the rotation depends to a large extent upon the yield of cotton. Cotton yields were highest in the three rotations B6–C, B6–D, and B6–E. In the first the application of manure materially increased the yield over the untreated rotation B6–A. Plowing under a green-manure crop as in B6–D, and subsoiling in addition to manure and a green-manure crop, as in B6–E, did not increase the yield over rotation B6–C. Alternate cropping of cotton and corn, with barnyard manure and plowing as practiced in B6–C, is the most desirable rotation in this series. Winter and spring plowing were less desirable than fall plowing.

In the 2-year rotations on field B5 sorghum was alternated with corn and with cotton. In both drills and rows the production of sorghum was better following corn than following cotton. The sorghum in these rotations yielded more than in any other rotation. Cotton and corn yields, however, were depressed by the sorghum crop.

The 3-year rotations included only the crops of milo, oats, sorghum, and Sudan grass. In three rotations, A5–A, A5–B, and B4–B, the crop sequence was oats for hay, cotton, and milo. Of these, A5–B appears to be the most desirable, as it has given higher yields of milo and cotton. The growing of field peas as a green-manure corp in B4–B apparently depressed the yield of cotton. In B4–A Sudan grass was grown in place of oats, and it is believed that this is a desirable crop sequence where a forage crop is desired in the rotation. In addition to the rotations tested there are, no doubt, other desirable 3-year rotations. Corn or forage sorghum might be introduced to advantage in any of these rotations, if desired.

There were only two strictly 4-year rotations. Although yields of milo, oats for grain, and forage sorghum were nearly average in these, the yields of cotton were low. Two years of sorghum preceded the cotton and it is probable that this was responsible for the low yield of cotton. While these rotations did not produce particularly high yields, a 4-year rotation is desirable on many farms, and it is believed that by introducing other crops in place of sorghum it would be possible to arrange a satisfactory 4-year rotation.

In these rotations barnyard manure increased the yields of cotton, milo, and forage sorghum, but failed to increase the yield of corn and depressed the yield of oats. Under the conditions existing at the San Antonio field station, where manure is obtained from outside sources, considerable difficulty in weed control is encountered. Green-manure crops have not proved of practical value under the existing local conditions. Cotton yields were depressed in a 2-year rotation with corn where rye was planted in the corn stubble, and also under continuous cropping where Canadian field peas were grown as a winter green-manure crop. The growth of both the rye and the peas is usually quite light, and it is believed the late spring plowing is the chief depressing factor. The value of subsoiling as practiced in this experiment varied with the seasons and also with the plot involved. On plots where the caliche gravel is close to the surface, subsoiling was of no value in any season, while on plots having deeper soil some beneficial effects resulted, especially during years when plentiful winter rainfall was followed by relatively dry spring and summer weather. Considering the entire period of the experiment, subsoiling was of no value (*4*). Late winter and spring plowing reduced the yields of cotton and corn in 2-year rotations as compared with summer and fall plowing. For corn, summer plowing following oats was found to be more desirable than fall plowing.

INFLUENCE OF COTTON ROOT ROT ON COTTON YIELDS

The root-rot disease of cotton, caused by a soil-inhabiting fungus (*Phymatotrichum omnivorum* (Shear) Duggar), is a serious limiting factor in the production of cotton in Texas, especially in the principal producing areas known as the "black lands." The disease attacks the roots, and plants continue dying from about the time the first squares appear until growth is stopped by frost in the fall (*5*, *6*, *7*, *9*, *10*, *14*). In general, it may be said that conditions of moisture and temperature that favor plant growth likewise favor spread of the disease. Since some plants are killed before making any cotton, while others succeed in producing a portion of a crop and still others produce a full crop before dying, it is very difficult to make a satisfactory estimate of the crop loss caused by root rot.

From a study of unpublished root-rot records, it appears that of all the crop sequences and cultural practices included in these rotation experiments, increasing the time between the recurrence of cotton in the cycle is the most effective factor in reducing the loss from this disease. Root rot was much more destructive in continuous cropping than in rotations and more extensive in 2-year rotations than in 3-year and 4-year rotations. The effects of green manure, barnyard manure, and subsoiling were found to be insignificant and to offer no practical means of controlling the disease. Sixteen months of clean fallow was not effective in reducing the loss from the disease.

Because of the various treatments given, it is not practicable to compare and correlate the yield of cotton with the loss from root rot as between rotations. The losses sustained within rotations are in some instances quite variable, and in such instances the influence of the disease upon the yield of cotton can be more satisfactorily studied. In Table 17 comparisons are made of the yields of plots within rotations that show wide variation in root-rot losses. If the loss from root rot is closely correlated with yield, then plots within a rotation receiving the same treatment but showing variations in the losses from root rot should reflect this difference in the yield of cotton. The yields from each plot in a rotation have been averaged separately for the years in which that plot was planted to cotton. The mean yield of all rotations has been averaged for the same years. The relation which the mean yield of a plot bears to the mean yield of all rotations for the same years is then expressed as a percentage. This has been done to eliminate the effect of differences caused by seasonal variations.

TABLE 17.—*Yields of cotton showing comparison of effect of high and low root-rot infection of plots within a rotation at the San Antonio field station, 1912–1929*

Rotation No.	Plot No.	Yield of seed cotton per acre										
		1912	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922
		Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
A4–A	1	------	350	------	500	------	388	------	8	------	170	------
	2	448	------	412	------	364	------	318	------	80	------	47
A4–G	15	------	------	------	------	290	------	------	------	240	------	------
	16	------	------	------	582	------	------	------	58	------	------	------
	17	------	------	582	------	------	------	114	------	------	------	235
	18	------	582	------	------	------	468	------	------	------	469	------
A5–A	1	------	596	------	------	674	------	------	44	------	------	183
	2	554	------	------	638	------	------	194	------	------	589	------
	3	------	------	728	------	------	600	------	------	392	------	------
A5–B	4	------	522	------	------	826	------	------	70	------	------	293
	5	600	------	------	578	------	------	222	------	------	614	------
	6	------	------	716	------	------	648	------	------	544	------	------

Rotation No.	Plot No.	Yield of seed cotton per acre							Mean for all years	Mean of all rotations for same years	Mean yields	Mean loss from root rot
		1923	1924	1925	1926	1927	1928	1929				
		Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Per cent*	*Per cent*
A4–A	1	324	------	0	------	1	------	0	193	314	61.5	41.4
	2	------	110	------	205	------	0	------	220	392	56.1	24.2
A4–G	15	------	266	------	------	------	0	------	199	293	67.9	21.2
	16	498	------	------	------	8	------	------	287	288	99.7	19.9
	17	------	------	------	386	------	------	------	329	433	76.0	.9
	18	------	------	0	------	------	------	0	304	335	90.7	3.7
A5–A	1	------	------	213	------	------	0	------	285	225	126.7	2.1
	2	------	332	------	------	17	------	------	387	380	101.8	2.0
	3	547	------	------	465	------	------	0	455	453	100.8	12.1
A5–B	4	------	------	136	------	------	0	------	308	225	136.9	1.7
	5	------	351	------	------	22	------	------	398	380	104.7	2.5
	6	538	------	------	472	------	------	0	486	453	107.3	18.0

The results shown in Table 17 indicate that there is very little correlation. In rotation A4–A, plot 1 yielded less than plot 2, and the loss from root rot was higher than in plot 2; however, the mean yields of all plots during the years plot 1 was in cotton were lower than when plot 2 was in cotton; and the mean yield of plot 1 was 61.5 per cent of the mean yield of all rotations, whereas the mean yield of plot 2 was 56.1 per cent of the mean of all rotations. In this case the yield fails to correlate with the loss sustained from root rot. In rotation A5–A, plot 1 had a small loss from root rot and also the lowest yield; plot 3 had a much greater loss from root rot than either plot 1 or 2, and yet the yield was considerably higher than either. This apparently is a negative correlation, but is to some extent explained by the reaction of all rotations. The yields of all rotations were higher for years when plot 3 was in cotton than for years when plots 1 and 2 were in cotton. The yield of plot 1 was 126 per cent of the mean of all rotations for the same years. The yield of plot 2 was 102 per cent, while the yield of plot 3, on which a much higher percentage of plants died from root rot, was 101 per cent of the mean yield of all rotations. In this case the yield was not reduced by the high loss from root rot. The reaction in A5–B was very similar to that in A5–A. In rotation A4–G the losses from root rot were quite variable. In plot 15 the loss from root rot was high and the yield was comparatively low. However, in plot 16 the loss from root rot was high and yet the yield, in comparison to all rotations, was equally as high as plot 17, in which only 0.9 per cent of root rot is recorded. From the foregoing it is evident that the loss from root rot can not be directly correlated with yields of cotton, even though the comparison is made on plots which received identical treatment.

SUMMARY

The rotation and tillage experiments here reported were conducted at the United States San Antonio Field Station, located in south-central Texas.

The soil where these experiments were conducted is a heavy black clay loam but is not as heavy as the typical black lands of Texas.

Rainfall distribution is the chief limiting factor in crop production. Although the mean annual precipitation is 26.46 inches, its occurrence is of such an erratic nature and evaporation is so high that the efficiency of the precipitation is low from the standpoint of crop production.

The original series of experiments was started in 1909, although some changes were made and a few rotations were added during the first four years. The purpose of these experiments was to ascertain what crops were best suited to the region and to find desirable crop sequences, as well as to determine the effect of various cultural practices on the yields of crops. The rotations were arranged so that each crop involved in a rotation was grown every year. This necessitated having as many plots devoted to a rotation as there were years in the cycle.

The detailed yields are given for each plot for each year. These show that oats are not a satisfactory crop for the region unless they can be utilized for pasture in addition to the hay or grain crop. Corn, milo, forage sorghum, and Sudan grass have produced satisfactory yields. Corn and milo are both good grain crops, although milo yields are reduced in many years by the sorghum midge and by birds. Cotton yields have been very low in recent years because of disease and pests.

The yields of oats were practically as high under continuous cropping as when grown in rotations. Yields were reduced by applications of manure but were not influenced materially by subsoiling or green-manure crops. Oats production is seriously handicapped by leaf rust and stem rust.

Corn yields were found to correlate very closely with rainfall received during the period November to July. Because rainfall is the chief limiting factor in the production of corn, the yields of the various rotations were very uniform. Yields in some rotations were higher than when continuous cropping was practiced, but in others they were lower. The best yields of corn were obtained from a 2-year rotation where early summer plowing following oats was practiced. Fall plowing following cotton produced better yields of corn than late winter plowing. Neither manure, green manure, nor subsoiling influenced the yields of corn materially.

Milo was found to respond favorably to applications of barnyard manure, but neither green manure nor subsoiling was beneficial. The highest yields were produced in 4-year rotations although those in 3-year rotations were very nearly as high. Continuous cropping of milo produced relatively low yields.

Sorghum for forage produced higher yields when planted in 8-inch drills than when planted in 4.1-foot rows, and the quality of hay was also superior. Sorghum produced higher yields when alternated with corn in a 2-year rotation than when alternated with cotton, both when planted in rows and when planted in 8-inch drills. The highest yields from drilled sorghum were secured in a 2-year rotation with corn. Yields of sorghum were greatly increased by applications of barnyard manure.

Sudan grass was found to be more desirable than sorghum as a forage crop, as it produced slightly higher yields and the hay was of better quality.

Cotton yields were generally higher in rotations than under continuous cropping. Rotations longer than two years did not appear to be more productive than 2-year cycles. Barnyard manure plowed under ahead of cotton produced increased yields in rotations, but under continuous cropping the response was insignificant. Yields of cotton were low following sorghum in all instances, but especially low in 2-year rotations of these crops. Neither green manure nor subsoiling consistently increased the yields of cotton or any of the other crops and in some instances had a tendency to reduce them.

The practice of fallowing land between alternate crops of oats, corn, cotton, or sorghum was found to be undesirable on shallow land with gravel substratum. The yields of corn and cotton were much below average; the yields of sorghum were no better than those secured in rotations; and although the yields of oats were above average, they were not high enough to justify the practice.

Bordering to prevent run-off of rainfall was found to be of no practical value. Yields of corn and cotton in a 2-year rotation on bordered plots were below average. The yield of sorghum when alternately cropped and fallowed on these plots was no higher than in rotations.

The application of barnyard manure was found to increase the yields of milo, forage sorghum, and cotton, but to depress the yields of oats; it had no influence either way upon the yields of corn.

In general, early plowing proved to be desirable. Corn and cotton yields were increased by early preparation of the ground.

LITERATURE CITED

(1) Ball, C. R., and Hastings, S. H.
1912. GRAIN-SORGHUM PRODUCTION IN THE SAN ANTONIO REGION OF TEXAS. U. S. Dept. Agr., Bur. Plant Indus. Bul. 237, 30 p., illus.

(2) Dean, H. W.
1905. THE SORGHUM MIDGE. (CONTARINIA [DIPLOSIS] SORGHICOLA COQ.) U. S. Dept. Agr., Bur. Ent. Bul. 85: 39–58, illus.

(3) Hastings, S. H.
1915. THE IMPORTANCE OF THICK SEEDING IN THE PRODUCTION OF MILO IN THE SAN ANTONIO REGION. U. S. Dept. Agr. Bul. 188, 21 p., illus.

(4) ——— and Letter, C. R.
1913. EXPERIMENTS IN SUBSOILING AT SAN ANTONIO. U. S. Dept. Agr., Bur. Plant Indus. Circ. 114: 9–14.

(5) King, C. J.
1923. COTTON ROOTROT IN ARIZONA. Jour. Agr. Research 23: 525–527.

(6) ——— and Loomis, H. F.
1926. EXPERIMENTS ON THE CONTROL OF COTTON ROOT ROT IN ARIZONA. Jour. Agr. Research 32: 297–310, illus.

(7) ——— and Loomis, H. F.
1929. COTTON-ROOT ROT INVESTIGATIONS IN ARIZONA. Jour. Agr. Research 39: 199–221, illus.

(8) Letteer, C. R.
1918. GRAIN SORGHUMS IN THE SAN ANTONIO DISTRICT OF TEXAS. U. S. Dept. Agr. Farmers' Bul. 965, 12 p., illus.

(9) McNamara, H. C.
1926. BEHAVIOR OF COTTON ROOT ROT AT GREENVILLE, TEX., INCLUDING AN EXPERIMENT WITH CLEAN FALLOWS. Jour. Agr. Research 32: 17–24, illus.

(10) ——— and Hooton, D. R.
1929. STUDIES OF COTTON ROOT ROT AT GREENVILLE, TEX. U. S. Dept. Agr. Circ. 85, 16 p., illus.

11) Ratliffe, G. T.
1929. A PROLONGED SAPROPHYTIC STAGE OF THE COTTON ROOT-ROT FUNGUS. U. S. Dept. Agr. Circ. 67, 8 p., illus.

(12) Scofield, C. S.
1919. COTTON ROOTROT SPOTS. Jour. Agr. Research 18: 305–310, illus.

(13) ———
1921. COTTON ROOTROT IN THE SAN ANTONIO ROTATIONS. Jour. Agr. Research 21(3): 117–125.

(14) Taubenhaus, J. J., and Killough, D. T.
1923. TEXAS ROOT ROT OF COTTON AND METHODS OF ITS CONTROL. Tex. Agr. Expt. Sta. Bul. 307, 98 p., illus.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE WHEN THIS PUBLICATION WAS LAST PRINTED

Secretary of Agriculture	Arthur M. Hyde.
Assistant Secretary	R. W. Dunlap.
Director of Scientific Work	A. F. Woods.
Director of Regulatory Work	Walter G. Campbell.
Director of Extension Work	C. W. Warburton.
Director of Personnel and Business Administration.	W. W. Stockberger.
Director of Information	M. S. Eisenhower.
Solicitor	E. L. Marshall.
Weather Bureau	Charles F. Marvin, *Chief.*
Bureau of Animal Industry	John R. Mohler, *Chief.*
Bureau of Dairy Industry	O. E. Reed, *Chief.*
Bureau of Plant Industry	William A. Taylor, *Chief.*
Forest Service	R. Y. Stuart, *Chief.*
Bureau of Chemistry and Soils	H. G. Knight, *Chief.*
Bureau of Entomology	C. L. Marlatt, *Chief.*
Bureau of Biological Survey	Paul G. Redington, *Chief.*
Bureau of Public Roads	Thomas H. MacDonald, *Chief.*
Bureau of Agricultural Engineering	S. H. McCrory, *Chief.*
Bureau of Agricultural Economics	Nils A. Olsen, *Chief.*
Bureau of Home Economics	Louise Stanley, *Chief.*
Plant Quarantine and Control Administration.	Lee A. Strong, *Chief.*
Grain Futures Administration	J. W. T. Duvel, *Chief.*
Food and Drug Administration	Walter G. Campbell, *Director of Regulatory Work, in Charge.*
Office of Experiment Stations	James T. Jardine, *Chief.*
Office of Cooperative Extension Work	C. B. Smith, *Chief.*
Library	Claribel R. Barnett, *Librarian.*

This circular is a contribution from

Bureau of Plant Industry	William A. Taylor, *Chief.*
Division of Western Irrigation Agriculture.	C. S. Scofield, *Principal Agriculturist, in Charge.*

U. S. GOVERNMENT PRINTING OFFICE: 1931

For sale by the Superintendent of Documents, Washington, D. C. - - - - - Price 10 cents